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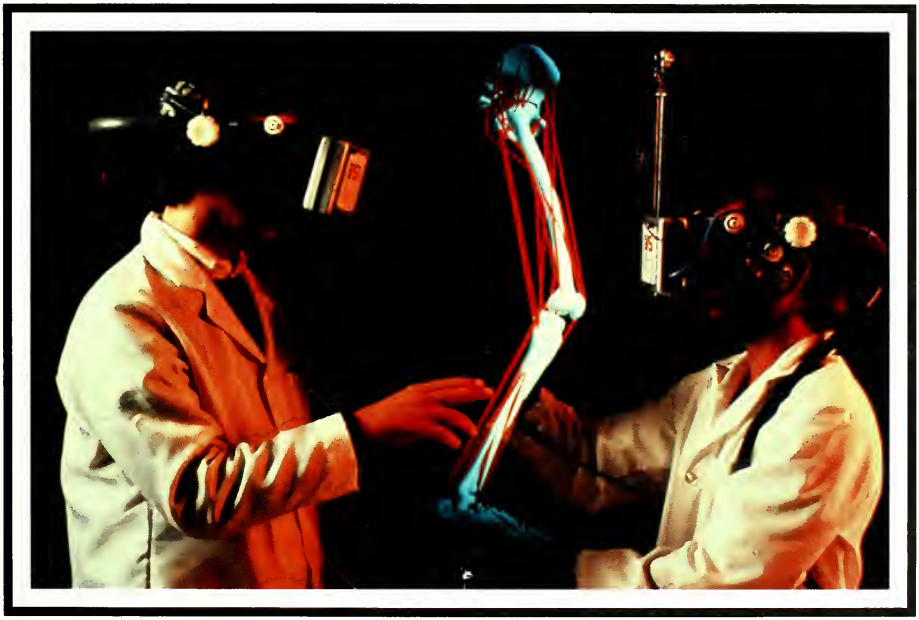
A Humanities Journal for Medicine and the Health Sciences



Simulation in Medical Education

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Introduction

Simulation in Medical Education

Howard S. Barrows, *Guest Editor*

This issue documents more than the range of simulations available in medical education. It also documents the remarkable resistance of medical faculty to new developments in education. Too often, they leave behind the forward-looking questioning, scientific approach they use in their clinical care and research roles and regress to entrenched, unquestioned tradition in their teaching roles.

Simulations support both the development and assessment of complex performance skills in realistic contexts, without risk and undo cost. Simulations can be manipulated in ways not possible in the real world to achieve a variety of educational objectives. Problems undertaken by the learner can be repeated until mastered. Activities undertaken by the learner in the simulation can be interrupted for feedback and discussion. The challenge of the task can be simplified or complicated. The stress of time limitation and conflicting demands can be amplified or attenuated. The same task or challenge can be given to each student, repeated without the variation that occurs in the real world. The task appropriate to level of learning can be presented to the learner at the most appropriate time in an educational program.

The teaching that goes on in many schools today resembles what was done centuries ago. The educational conservatism of medical faculties is well characterized in their adoption of simulations. Educational innovations in medical education have great difficulty getting a foothold. Both the standardized patient technique described in this issue by Peggy Wallace and the simulated anesthesia patient described by Stephen Abrahamson were developed over a quarter of a century ago. Their adoption was inhibited for many years by the prevailing attitude of academic physicians in this country and in Europe that there were always patients available for practice by students and residents—simulations were an unneeded expense and obviously unreal. Medical care has changed drastically over the last fifteen years, and the usual "charity" patient is no longer a limitless supply as was the case when these simulations were developed. In many settings, the shortage of patients available for practice by students has been the stimulus for an interest in simulation—not concern for the well-being of patients. The need for standardization and availability of appropriate patient problems for skill assessment and the discomfort and risk to patients during student and resident learning were never compelling arguments for most medical teachers.

The torturous and slow course of standardized patient development is well chronicled by Wallace. It is a testimony to persistence by those few who saw the potential value of the technique. Now, the standardized patient is ubiquitous in medical education. Medical educators are finding valuable new ways of not only employing the technique but also enhancing its value, reliability, and validity. It is impossible now for many to imagine that there could have been objections or reservations about using standardized patients—the need is obvious.

Abrahamson's story of Sim One reads like a tragedy. Sim One was not only inhibited, it was destroyed by those unable to appreciate or care about its unique and humane value to the care of patients, despite remarkable persistence by its innovators. As you read the evaluations that were carried out on Sim One's effectiveness you can only imagine the lives and suffering it saved—the dummy could be injured and die many times as students learned. Now that the employment of space-age computer technology has made incredible simulations prevalent, it might be difficult to believe the short-sightedness of those in the Los Angeles County Hospital who did let Sim One die, not of poor skills in intubation and anesthesia but of neglect. Abrahamson and his cohorts used state-of-the-art postwar technology thirty years ago to create an incredibly realistic and responsive patient dummy that could challenge and record the wide variety of skills required in giving anesthesia. They were way ahead of their time! A few months ago I sent Abrahamson a clipping from a newspaper in Cambridge (UK) describing a clever new idea in medical education that was developed there—a dummy that could be used for training in anesthesia.

Victor M. Spitzer's paper on the Visible Human Project introduces anatomical simulations of the human body that can be viewed from any aspect and cut in any type of section. The viewer can travel through the body in any path through sections, construct three-dimensional images, identify systems and organs within their whole body contexts, and carry out surgical procedures and interventions with tactile feedback from the structures punctured or cut. The educational implications and possibilities of this ability already boggles the mind, yet Spitzer hints of even more. He suggests future integration of physiological phenomena into the anatomical data, adding an understanding of tissue function to the already incredible displays. His other suggestion for future incorporation of similar embryonic-through-geriatric anatomy with the adults he now has adds the fourth dimension of time to those three-dimensional displays. Not content with that, he hints that by incorporating other developing data we may eventually travel back phylogenetically to look at human evolution. He has a great vision, and the educational implications are almost beyond comprehension.

The paper by Richard M. Satava and Shaun B. Jones is an exciting, comprehensive update on where computer technology has taken us with the simulations created in the world of virtual reality. What is being accomplished seems almost unbelievable. The simulations not only allow for practice and assessment but are designed to enhance surgical technology applied to patients. I thought that perhaps times had changed in the attitude of medical faculty about simulations, but then I heard about a recent conference where virtual surgery simulations were presented.

Portrait of Lynn Taylor, one of the very first simulated patients trained by Howard Barrows for instruction of neurology clerks at the Los Angeles County General Hospital. In his 1971 volume introducing the use of simulated patients in medical education, the author notes that artists' models as well as amateur and professional actors and actresses can be excellent groups to draw from in recruiting simulated patients. He advises those starting a program to inquire at the local drama department or a local amateur or professional acting society about potential interest, but to recognize that the most important qualities of a successful simulated patient are intelligence, a flair for personal acting, and a willingness to be demonstrated, interviewed, and examined as a patient. The portrait is the work of Phyllis Barrows who, at the time of painting, was unaware that the model was one of the pioneer standardized patients then being trained by her husband.

A number of surgeons at the conference were up in arms about the suggestion that their skills could be improved upon, if not replaced, by such simulations.

Theodore R. LeBlang describes the simulation of an actual courtroom trial involving important medicolegal issues for the education of medical students. It is compelling for students as medical faculty and local prominent legal professionals simulate the people involved. It's far more realistic and meaningful than either reading the case or watching a television demonstration. It would be interesting to see if down the line the medical students could be actively involved and play the medical roles in the courtroom drama—so much more might be learned about preparation for those roles they might have to play in their clinical lives.

As these collected papers show, the stage has been set in medical education for teachers to value simulations for their educational value in facilitating skill development and direct assessment of performance competency without risk and undue cost. Perhaps some health science journal a decade into the future will show ingenious simulations developed in a more accepting climate for educational innovation.

♦

HOWARD S. BARROWS is presently the Chair of the Department of Medical Education at Southern Illinois University School of Medicine. In the early sixties, while directing the neurological service and residency program of the Los Angeles County Hospital, he developed the technique of training people to simulate patients (simulated patients, standardized patients) for teaching and assessment in medical school. In the seventies, he developed the technique of using standardized patients for teaching, particularly in problem-based learning. In the early eighties, he pioneered the development of the multiple-station, clinical practice examinations using standardized patients to assess the clinical competencies of medical students. Through many publications, demonstrations, consultations, and workshops he has encouraged the dissemination of the use of standardized patients in medical and health science schools. He is the author of *The Tutorial Process*; *The Clinical Practice Exam: Six-Year Summary*; *What Your Tutor May Never Tell You: A Medical Student's Guide to Problem-Based Learning*; *Developing Clinical Problem-Solving Skills: A Guide to More Effective Diagnosis and Treatment*; and *Practice-Based Learning: Problem-Based Learning Applied to Medical Education*. The National Board of Medical Examiners honored him as the first recipient of the John Hubbard Award.

Following the Threads of an Innovation: The History of Standardized Patients in Medical Education

Peggy Wallace

Prologue

The emblem of the medical profession, the caduceus, was given to Hermes, messenger of the gods, by Apollo, the God of Medicine, who empowered the winged staff to bring peace out of conflict. Skeptical, Hermes tested Apollo's declaration by planting the golden winged rod between two fighting serpents at which point they both entwined themselves in opposite directions onto the staff, ending up facing one another in reconciliation. That totality, the caduceus, is a symbol of integration. It is the weaving of conflicting elements together into wholeness, no longer "either-or," but rather "both-and": science and art, teaching and testing, knowledge and compassion, theory and practice, technology and the person, doctor and patient, illness and recovery. It refers back to the method of Hippocrates, the Father of Medicine, and to that of Apollo's son, Asklepios, the God of Healing. It goes back to the Oath of Hippocrates taken by all who are about to embark upon the practice of medicine. In addition to a code of ethics by which the new physician will live in the fellowship of the medical profession, the Oath honors the relationship and responsibilities of student to teacher/teacher to student.

Underneath the history that is about to unfold are many untold stories of the teachers and the students, the famous and the unknown, whose endeavors, trivial and distinguished, hold the wisdom of the serpents on the staff of the innovation. After thirty years, the standardized patient now supports that knowledge and holds in the caduceus's paired wings, the inspiration for learning from the immediacy of the human encounter. The student and the teacher coming together to discover the wisdom and the meaning of the profession that chooses them.

The caduceus

Introduction

The term *standardized patient* (SP) has gone through many metamorphoses as the process itself has been refined since its inception in 1963. There have been many other names attempting to describe this phenomenon: programmed patient, patient instructor, patient educator, professional patient, surrogate patient, teaching associate, and—the more generic term—*simulated patient*. What all of these terms are referring to is a person who has been

carefully trained to take on the characteristics of a real patient in order to provide an opportunity for a student to learn or be evaluated on skills *firsthand*. While working with the standardized patient, the student can experience and practice clinical medicine without jeopardizing the health or welfare of real, sick patients. The value is in the *experience* of working with a patient. It takes the process of learning a step beyond the books and away from reliance on paper and pencil tests. It puts the learning of medicine in the arena of veritable clinical practice—not virtual reality, but veritable reality—as close to the truth of an authentic clinical encounter as one can get without actually being there, because there is a living, breathing, responding human being to encounter.

The expression "standardized patient" was coined by the Canadian psychometrician Geoffrey Norman, who was looking for a designation that would capture one of the technique's strongest features, the fact that the patient challenge to each student remains the same.[1] The term was adopted and generally accepted in the 1980s, when the focus of medical education research using simulated patients turned sharply toward research in clinical performance evaluation. The standardized patient offers the student an opportunity to come face to face with the totality of the patient, with his "stories," physical symptoms, emotional responses to his illness, attitudes toward the medical profession, stresses in coping with life, work and his family—in other words, everything a real patient brings to a clinician, overt and hidden (except the necessity of actually "making the patient better"), allowing the student to go about the *process* of unfolding all that he feels he needs to know from the veritable interaction with the patient in order to assist that person to heal.

The Threads: The Innovators

The 1960s

Today, as we enter the new millennium, the standardized patient has become one of the most pervasive and highly touted of the new methodologies in medical education. But it was certainly not always so. The standardized patient was anything but a welcome and readily accepted educational tool, especially in the early days. Its acceptance was tentatively held at arms length, criticized as too touchy-feely, too expensive, too "Hollywood." Perhaps the last charge was made because the first simulated patient was born, if not in Hollywood, very close by, in Los Angeles at the University of Southern California (USC).

The father of this innovation in medical education and the most convincing herald in the history of the use of standardized patients is the neurologist and medical educator Howard S. Barrows, who gave birth to the first simulated patient in 1963 when he was teaching third-year neurology clerks at USC. It was not an auspicious beginning. In fact, for the whole of the time that Barrows taught at that institution, "No one else at USC was even interested in using it. . . . Nobody was even interested in trying it."[2] In those early days, Barrows was often invited to speak about neurological subjects, but frequently was requested *not* to talk about simulated patients. In fact, he was seen as doing something quite detrimental to medical education, maligning its dignity with "actors." As soon as the Associated Press got hold of the idea, it was promoted in the popular press by such headlines as:

"Hollywood Invades USC Medical School"[3] and such descriptions of simulated patients as: "Scantily clad models are making life a little more interesting for the USC medical students."[4] This made it all the more difficult for Barrows to convince his medical colleagues that the technique he was using to teach medical students was a legitimate educational tool. Their resistance persisted even after the 1964 publication of the first article on simulated patients, "The Programmed Patient: A Technique for Appraising Student Performance in Clinical Neurology" in the *Journal of Medical Education*.[5] Barrows's coauthor on this landmark article was Stephen Abrahamson, director of the USC Division of Research in Medical Education.

The USC dean received complaints from medical schools all over the country but just decided to ignore them. However Barrows, in an attempt to legitimize the work to which he was becoming so committed, replied individually to the dean or associate dean at every single one of the complaining medical schools, sharing copies of the *Journal of Medical Education* article.

Barrows went to such trouble and persisted in using the simulated patient in his clerkship for no other reason than the fact that "it was working." Students loved the technique, and, as he said, "I was learning things about those students I would have never found otherwise."[6] Barrows was searching for an alternative to the traditional method of evaluating students on their clinical clerkships, an unsatisfactory procedure that persists even today.[7] When faculty got together at the end of a clerkship, Barrows remembers the conversation going something like this: "Let me look at that student's picture. . . . Well, I think I remember him." Typically, according to Barrows, most clerks received satisfactory or better evaluations. "And I knew it was because of the way they combed their hair or how neatly they dressed or if they said 'Yes sir' and 'No sir.'"[8] Almost never was there a student whose clinical skills were evaluated as unsatisfactory because the faculty almost never directly observed a student with patients. In fact, until the advent of standardized patients, there was no objective clinical measure by which to evaluate students.[9]

As with most innovations, several events occurred in Barrows's experience that planted the seeds for the birth of the first simulated patient. In 1959–1960, during his last year as chief resident in neurology at the New York Neurological Institute, Columbia-Presbyterian Medical Center, Barrows worked on the service of a professor by the name of David Seegal who "would sit and watch every single medical student work up a patient completely from beginning to end. That took at least an hour for each student." When Barrows asked him why he was spending so much time doing this, Seegal responded: "Nobody in medical school ever watches these fledgling medical students. . . ."[10] Barrows realized that because of Seegal's commitment to direct observation of the students, he was finding a number of skills on which the students could improve because they had not known they were doing them incorrectly.

The other seminal event occurred around the same time when Barrows, who was responsible for finding neurological patients for the board examination in psychiatry and neurology, ran into Sam, a

patient who had been the subject for this examination a number of times:

> Following the examination, the director of the Montefiore neurology service made rounds on his patients to see how they had tolerated the numerous examinations they had had to undergo during the examination. He interviewed a patient known to everybody as Sam, who had syringomyelia. When asked about the examination, Sam remarked that there had been no particular problem except with the physician who had examined him last. Sam indicated that that physician had been quite hostile and had performed a very uncomfortable neurological examination. The director said that he was sorry to hear that, but Sam said, "Don't worry, I fixed him—I put my Babinski on the other foot and changed my sensory findings."[11]

Barrows's first full-time faculty position was in the Department of Neurology at USC. It was there, in the early 1960s, that he met Stephen Abrahamson, the renowned medical educator who had just been recruited to establish one of the first departments of medical education in the country. They developed a relationship that inspired the exploration of a number of innovative educational methodologies. To illustrate, shortly after he arrived at USC, Abrahamson introduced the 8mm single-concept film cartridge, one of the latest innovations in media, at a conference on medical education in Los Angeles. Barrows immediately sensed its potential. He saw how he might be able to use it in teaching the normal neurological examination by documenting each part of the exam on a series of four-minute, single-cartridge film loops. Needing a person who was completely comfortable being the subject for such a demonstration, Barrows went to the USC Art Department and hired an artists' model, Rose McWilliams. Those 8mm cartridges were used by students to learn the neurological exam on the clerkship, and as a refresher for residents who might want to review a specific part of the exam before working with a patient.

However, Barrows still had the perennial clerkship evaluation dilemma. "I had the film loop and I had Rose. And suddenly I thought, 'I wonder, if I could teach Rose, like Sam, to have a neurological problem.'"[12]

In order to evaluate the clerks, Barrows needed a case about which he knew everything—all the signs, all the symptoms. He needed a case that could be reproduced for every single clerk in exactly the same way, and he needed someone who had the time and the knowledge to record what happened in each encounter with the patient. Seegal's detailed understanding of the clinical competence of his clerks and Sam's ability to create his own simulated findings inspired Barrows to create Patty Dugger, the first standardized patient case, which was performed by McWilliams.

Patty Dugger, a paraplegic woman with multiple sclerosis, was based on a Los Angeles County Hospital patient. It is a case that is so impressive in its simulated findings that Barrows still continues to use it in demonstrations around the country. Others have found this case so rich that it has shown up throughout the years in various learning, assessment, and research projects, and is, even today, still being experienced by some students in their clinical clerkships at a number of medical schools.

After the case was developed, the question of how to actually do the evaluation arose. "Should I peek through a drape, or what should I do? I finally decided that I would make [a] checklist that Rose would fill out afterwards."[13]

Barrows monitored Rose and the students from time to time, but it was Rose who was primarily responsible for recording what happened with each student during every encounter.

So the birth of the standardized patient came out of a need for a more rigorous method to evaluate the clinical skills of third-year medical students. The methodologies designed by Barrows, from what he called a "pretty primitive" first effort, are the source of the procedures currently being refined by the National Board of Medical Examiners (NBME) and the Educational Council for Foreign Medical Graduates (ECFMG) for their anticipated clinical competence exams, to be included as part of licensure, sometime around the turn of the millennium.

Barrows was learning all kinds of things about the students on his clerkship that he knew were absent on the other clerkships, but none of the faculty were willing to change. Abrahamson had helped him legitimize the simulated patient technique outside of USC, but Barrows was still meeting with such total resistance from neurologists that he began to think about other options. "Here I am a neurologist," he recalled, "and my interest is in teaching neurology. I had a tool. Neurologists were not interested in that tool [so] I eventually became interested in working with people in other fields. I remember deliberately making that decision when I was at McMaster."[14]

After having spent a sabbatical year in Canada in the late 1960s, Barrows left USC in 1971 to become one of the founding faculty at McMaster University in Hamilton, Ontario, "because it was a much more understanding climate."[15] McMaster had a new medical school, the first with an entirely problem-based learning (PBL) curriculum.

The 1970s

Along with his use of simulated patients to evaluate medical students, Barrows began to see the value of simulated patients in teaching and research. At the same time, he started reaching out to other practicing physicians by designing workshops to help them improve their neurological skills. Barrows's underlying philosophy in these workshops was experiential learning, learning by doing and receiving immediate feedback.

Photograph taken at the Los Angeles County/University of Southern California Medical Center of Howard S. Barrows training the first "Patty Dugger" (Rose McWilliams) to produce a Babinski response when her foot is being scratched

Primary among a series of such seminal workshops during the 1970s, that relied heavily on the use of simulated patients, were the "Bedside Clinics in Neurology," sponsored by the American Medical Association (AMA).[16] The day before the workshop, Barrows would bring in five prominent neurologists from around the country (who would serve as tutors for the workshop participants) and an equal number of simulated patients. The SPs were not only trained to perform several neurological cases, but they were also trained to simulate typical continuing medical education participants, such as "the one who isn't interested, the one who's always asking incredible questions, interfering with everybody else."[17] This gave the neurologist-tutors an opportunity to practice and learn how to work effectively with the simulated patients and the neurological cases as well as with the types of physicians with whom they might find themselves working the following day.

During the workshop, each neurologist-tutor was assigned a group of five or six physicians. The challenge was "to make his group of physicians perfect by the end of the day."[18] Each group would start with one simulated patient and work through a case using the "time in-time out" technique. "Time in-time out" was first used by Barrows at McMaster to enhance small group teaching. By calling a "time out," the interview was "put on hold," allowing the students an opportunity to discuss among themselves any number of issues that had arisen in the encounter as well as to brainstorm where they might like to take the interview when they went back to "time in" with the simulated patient.

During the Bedside Clinics, it was the responsibility of the tutors to detect the problems the individuals in their groups were having and then focus their next simulated patient experiences in those areas. As Barrows pointedly stated, "If you ask most physicians what they don't know, they don't know they don't know what they don't know."[19] This premise is true for students of all ages, no matter how experienced they are. If the students always knew what they didn't know, they could probably figure out how to learn it on their own.

In addition to Barrows's strong belief in the efficacy of experiential and participatory learning, there is another principle in his educational philosophy that sheds light on his approach. As much as possible, Barrows believes that the student should be given an opportunity to learn in the same manner as the student is going to practice. The germ of that principle can be traced to some work that Barrows did at Michigan State University (MSU), in the early 1970s, with Hilliard Jason, Arthur Elstein and Lee Shulman of the Office of Medical Research and Development (OMRAD).

After seeing a demonstration of the Patty Dugger case at the annual meeting of the Non-Group Society (now known as the Society of Directors of Research in Medical Education [SDRME]), Hilliard Jason, the director of OMRAD, was so impressed with the technique that he established a simulated patient program in the first two years of medical school at MSU. He designed four "difficult patient" cases for the students to experience: a hostile patient, a seductive patient, a patient from another culture, and a patient who hated physicians. During the student interviews, two cameras simultaneously recorded individual shots of the student and the simulated patient. These close-up images were electronically placed side-by-side in a single, split-screen image so that when Jason later reviewed the videotaped encounter with the student, the actions and the reactions in both the student and the simulated patient could be observed simultaneously. It was one of the first of many educational applications inspired by Barrows's simulated patient work.

Shortly thereafter, Shulman invited Barrows to develop a couple of simulated patient cases that he and Elstein wanted to use, on a new research project conceived by Hilliard Jason, to try to determine how physicians solve problems.[20] They were using *stimulated recall,* a technique developed by a colleague, the noted psychologist Norman Kagan. Elstein and Shulman encouraged Barrows personally to go through their research protocol using this technique. The physician was encouraged to do his usual workup of a patient while being videotaped. The researchers immediately reviewed the encounter with the physician, stopping and starting the tape, asking the physician to recall what was

going on in his mind at various moments in the encounter.

It was such an enlightening experience for Barrows that it inspired him to use stimulated recall to explore the thinking process of other practicing neurologists, and then to do the same with his residents and students. What struck Barrows when he experienced the stimulated recall at MSU was that he was not teaching in the same way that he was practicing. As he recalled:

> So many faculty teach students to do a complete history and complete physical. There is no such thing. Ask every question, do everything on physical, there is no such thing. And when they get into real life, they're lucky if they have twenty minutes with a patient. And if they're in an emergency, they're lucky if they've got five minutes. You can't ask every question. So they have to know the right questions to ask.[21]

The discoveries about clinical reasoning were so potent for Barrows that he changed his approach to education, no longer teaching students the "complete" history and physical exam, the way he was taught. Instead, he provided the students with the infinite possibilities a patient provides by letting the students ask anything they wanted, either in direct interaction with a simulated patient or by building that kind of flexibility into written patient problems. In this way, the student learned what questions did—and what questions did not—have a "payoff" in relation to their hypotheses. The goal was not to memorize an exhaustive list of questions and physical exam maneuvers. It was to guide the students into learning what were the *appropriate* questions and maneuvers while helping the students think through their assumptions of what might be wrong with the patient.

While at McMaster, Barrows provided another significant contribution by expanding the potential use for the simulated patient, at the same time affirming the authenticity of the SP performance methodology. One complaint often heard about the formalized assessment of clinical skills revolves around the question of physician performance—not in the examination setting, but in the day-to-day clinical practice setting. In other words, how realistic would an SP appear to the physician unaware that the patient is simulating a case? In one McMaster study, the simulated patients were scheduled in the physician's office unannounced. The skills and quality of the physician's performance were then determined by comparing the reports made by the standardized patients, who were undetected as simulations, to the physician's office records.[22] This study has inspired a number of similar studies throughout the intervening years.

Besides Barrows, there are a number of other threads that weave together to shape the history of standardized patients. Also significantly responsible for establishing the standardized patient as both a credible teaching methodology and a reliable evaluation tool is the pediatrician Paula Stillman. There have been a number of organizations as well: the Josiah Macy, Jr. Foundation, the Liaison Committee on Medical Education (LCME) of the American Medical Association, the National Board of Medical Examiners (NBME) and the Educational Council for Foreign Medical Graduates (ECFMG). These organizations, which have been primarily responsible for the firm establishment of this technique in medical schools throughout the United States, as well as Stillman and a number of other less well-known clinician educators, have all

been influenced by Barrows's continuing enthusiasm, persistence and effectiveness in advocating the use of the standardized patient over the past three decades.

Contributions of Paula Stillman

In the early 1970s, when she was the pediatric clerkship director at the University of Arizona in Tucson, Paula Stillman started using simulated mothers as a technique for teaching interviewing skills. She was inspired by work being done at MSU by another pediatrician, Ray Helfer, who had trained "programmed mothers" to give histories of common pediatric complaints. Helfer, no doubt influenced by the stimulated recall research at MSU, employed graduate students to review the tapes of each medical student encounter, then code their behaviors into some twenty-five categories.[23] Stillman found the process complicated and cumbersome. When she returned to Arizona, she was determined to develop a better instrument for teaching and assessing both the content and the process of medical interviewing—an instrument that would be based on behaviors, not abstract ideas, so that it could also be used for giving feedback to the students. The Arizona Clinical Interview Rating Scale (ACIR)—or "Arizona Scale" as it became known—was the first behaviorally-anchored Likert scale to assess medical interviewing skills.[24]

The histories Stillman taught her simulated mothers to give were compilations of the stories of several children, often including their own, laid out in the format of a checklist. She also taught the mothers how to use the checklist, to record whether or not a given item was asked, and then to give feedback to the students on their interviewing skills.

> I wasn't doing anything fancy with simulation. It was strictly common pediatric problems and, by that time, well accepted interviewing skills. The mothers would play the role of the patient and then, at the end, they'd go over the content checklist and the process checklist. In the beginning, I used to videotape everything. But [the mothers] got so good at remembering specifics when they gave feedback that I stopped videotaping.[25]

Then, in the mid-1970s, Stillman was asked to run the physical diagnosis course. She was advised by her colleagues not to accept the position because she was too young to take what was considered to be "a dead-end job." But Stillman was drawn to education, and she saw this as an opportunity to expand the work she had started in the pediatric clerkship. She was curious to see if she could develop something for the physical exam that was similar to the interviewing scale. Stillman felt the problem with existing physical exam checklists was that they were too vague and mostly in outline form:

> Examine the Heart, Examine the Eyes, Examine the Abdomen. They weren't teaching tools. By reading the checklists, you couldn't tell what behavior was expected. So I developed a physical exam checklist, with family practitioners and internists, [that] had over 200 items on it. It broke down each component of the physical exam, so when it said "Examine the Eyes," there were twenty things you had to do when you examined the eye.[26]

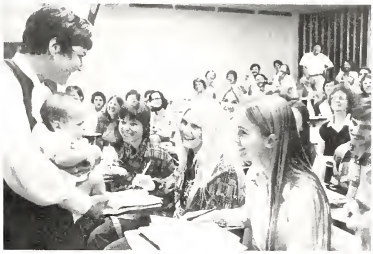
Stillman found a healthy man and a healthy woman, the first "patient instructors," whom she taught to use this checklist.[27] Not only did they know what it felt like when each maneuver was done correctly, but they knew how to teach the student to do it properly. As she explained, "[I]f you weren't reaching up high enough

in the axilla when you were palpating the axillary lymph nodes, they could teach you how to do that. They knew nothing about medicine. They were strictly process people."[28] Stillman's patient instructors were not simulating a real patient, they were using their own normal bodies to teach the medical students how to do a complete, accurate physical examination using a detailed checklist designed by clinicians.

The only other physician doing anything of similar import, at that time, was the obstetrician/gynecologist Robert Kretzschmar, at the University of Iowa. In 1968, inspired by Barrows's early work with simulated patients, he developed the first "gynecology teaching associates" (GTAs). The GTAs, using their own bodies, were trained to teach students and give them feedback on how to do a proper pelvic exam.[29] In the beginning, the identity of the GTAs, then known as "professional patients," was obscured by covering the women's faces.

> The patient's responsibility was to note the various motions and sensations of the physician's examination and compare each student's performance against these criteria. She therefore gave minimal feedback to the student on his technique. . . . The simulated patient concept, in this rudimentary form, succeeded in providing a conducive environment for instruction with a relaxed, live model, but it did little to enhance communication between student and patient or reliably evaluate a student's technical performance.[30]

By 1972, Kretzschmar had greatly expanded the role of the GTA. No longer were the patients' identities masked. The GTA had been given increased responsibilities, including teaching the unique communication skills that go along with the practical skills of a quality pelvic examination. Kretzschmar saw that integration of the two skills was primary. In the open climate of the 1970s, his approach to the learning of this sensitive examination was readily received by the Ob/Gyn profession, by the women who participated in the program, and by those who benefitted from it. Within a few years, a number of medical schools started their own GTA programs, many of which are still in existence today.



Paula Stillman with her youngest patient educator, Alexandra Roberts, at the University of Arizona School of Medicine

Stillman eventually invited Kretzschmar to the University of Arizona to speak about his work. In the meantime, with her normal physical-exam patient instructors in place in her second-year physical diagnosis course, Stillman knew she "could guarantee that before each student entered his third-year clerkship[s], he could go through a systematic physical exam."[31] She felt confident in the process, until one day she observed a senior medical student who was examining a patient with severe bronchiectasis:

> I said to him, "What do you hear?" And he said, "I don't hear anything. The lungs sound normal." And I said, "Has anybody ever checked out your findings?" And he said, "No, but I listened all over the chest and I percussed." And I realized that I never checked

that the students could differentiate normal from abnormal.[32]

This awareness inspired Stillman to search for patient instructors who had actual physical findings:

> Tucson [had] a wonderful population of patients with chronic diseases who were very smart and who had made enough money that they could retire early and really didn't have much to do. I found a man with terrible bronchiectasis who had been an engineer for an astronomical observatory who couldn't work anymore. I found a woman with severe aortic stenosis. I found another one with severe asthma. I found a woman with severe arthritis.[33]

These four were the original patients with chronic findings. Stillman trained these patients to use her normal physical-exam process checklist along with a new content checklist that she designed to take into account the specifics of the actual findings of each patient instructor. She then taught the patients both how to examine themselves, and how to teach the students to detect the abnormality on their own bodies.[34] For instance, in teaching the student, the patient would place the stethoscope properly on her own body until she could hear her own abnormal finding, then she would hold the diaphragm in place while the student listened through her stethoscope. Stillman explained that the patient would then describe in detail the features the student should be listening for: "This is a systolic murmur. First, you [will] hear S1 and then you [will] hear the murmur starting after S1."[35]

Stillman used this method in lieu of simulation "because I had this extraordinary cadre of patients. By the time I left Arizona, I must have had seventy-five patients who had chronic stable findings [in] every organ system."[36] In working with these men and women and honoring them as co-educators, Stillman commanded such respect and dedication to the goals of her teaching program that, even after she left to take a position at the University of Massachusetts, many of those same patients continue years later to hold her inspiration in their present-day work with students at the University of Arizona.[37]

The next development for Stillman was an integration of the split: "I realized that I was doing the history and I was doing the physical and I had never really put it together."[38] So she began working with some of the patients with chronic stable findings, simplifying their complicated histories, and putting together for them both history and physical in lengthy 45-minute encounters to use with her residents.

About this same time, in the mid-to-late 70s, Stillman began to invite people who she felt were doing "interesting work" in medical education to present their studies in Arizona. Among them were Kretzschmar, Abrahamson, and Barrows, all of whom had developed a body of sophisticated simulations. As usual, Barrows brought a standardized patient to help demonstrate his simulation techniques. The patient enacted several cases demonstrating what most people would assume to be impossible symptoms to simulate, including a pneumothorax and a comatose patient with Cheyne-Stokes breathing who, upon stimulation, throws a decerebrate fit and stops breathing. Stillman was impressed. "I had never seen this before," she said. "I thought this was the most extraordinary thing I had ever seen. I wasn't doing work with simulation because my patients had real findings."[39]

That simulated patient with the impressive simulated findings was Robyn M.

Tamblyn, a nurse who was working with Barrows at McMaster. Tamblyn, another enduring thread in the history of standardized patients, went on to write her doctoral dissertation on the emerging standardized patient methodology.[40] She continues to work in the field of medical education and has made significant contributions to the standardized patient literature.

In 1982, when Stillman became Associate Dean for Curriculum at the University of Massachusetts, she realized she couldn't replicate the University of Arizona program exactly as it was. "I started to do work with simulation [in Massachusetts] because . . . I couldn't find that incredible pool of brilliant patients with chronic stable disease."[41] Stillman has written, published, and presented on her work from the beginning, but the truly significant contributions she has made to this field were about to come, starting with the work she did in New England in the 1980s.

The names of Howard Barrows and Paula Stillman appear like interweaving threads throughout the history of standardized patients. Where Barrows started using simulation in demonstrations and for summative evaluation, Stillman began her work using patient instructors for teaching and formative assessment. Though both started with checklists, up to the early 1980s, their two approaches to education were different. Barrows's exploration of the principle "learn-medicine-as-you-will-practice-it" led him to incorporate the less tangible elements of the clinical reasoning process into his version of problem-based learning. The veritable encounters he designed for students with simulated patients integrated cognitive learning and practical experience into the "messiness" of human interaction. Stillman's exploration was based on improving traditional educational methods. She focused on concrete behaviors, thoroughness in the basic skills of interviewing, medical history-taking and physical exam to assure that students were prepared for their required clinical rotations. However, for both Barrows and Stillman, the simulated patient became the vehicle by which they were able to investigate their clinical education insights, realize the significant accomplishments of those explorations, and, in so doing, hold the threads until the climate was conducive for others to weave in their own investigations.

The 1980s and 1990s

In 1981, Barrows left McMaster to become Associate Dean for Education at Southern Illinois University (SIU) School of Medicine. It was there that his emphasis in using the simulated patient changed from "a personal tool for a neurologist with teaching and assessment responsibilities to a tool for the development of medical education programs in the curriculum."[42] In June 1984, on the anniversary of the tenth commencement of the SIU School of Medicine, Barrows and a number of others "felt that this milestone should be celebrated in conjunction with another event affirming the school's mission. . . . The increasing national concern about curricular abuses suggested that a conference focusing on curricular reform issues would be appropriate."[43]

This invitational conference, "How to Begin Reforming the Medical Curriculum," co-sponsored by the Josiah Macy, Jr. Foundation and the SIU School of Medicine, ignited the adoption of standardized patients, exploding their use in medical schools across the country. Up

to that point, simulated patients were seen, by all but a few fervent advocates, as not much more than an interesting educational device. This conference provided the impetus to begin scrutinizing the efficacy of evaluating clinical competence by using standardized patients in multiple-station, performance-based assessments. The standardized patient examination was beginning to be seen not only as a valuable tool for individual student assessment, but, more potently, as the means for instigating curricular change in medical education.

In an effort to convince deans and associate deans of the usefulness of standardized patients, the Macy Foundation supported a number of follow-up experiential, standardized patient demonstrations. The first of these, "Newer Approaches to the Assessment of Clinical Performance," occurred in October 1984, when the attendees of that first invitational conference, which had taken place four months earlier, were invited back to SIU for a hands-on, multiple-station standardized patient demonstration that took place in the first fully-equipped, dedicated simulated clinic in the country. Designed by Barrows, this Professional Development Laboratory, as he called it, became the model for other schools as standardized patient programs grew and the need for dedicated clinic space became a reality.

No other demonstrations were funded by the Macy Foundation until just before Thomas H. Meikle became president. Meikle, himself a former dean of the Cornell University School of Medicine, knew that if this new standardized patient methodology were to have a chance of getting a toehold in medical schools, it would be the deans of the schools who would need to be convinced of its value. Meikle put together a blue ribbon committee chaired by David Rogers, to study clinical medical education, particularly performance-based assessment. One of the six recommendations for medical school faculties that came out of that conference was to "require medical students to pass comprehensive performance-based clinical examinations" before graduating.[44] Following this conference, his vision of the importance of clinical skills assessment reinforced, Meikle "began a process basically to educate deans and to educate my board."[45] The 1960s education mantra "Evaluation drives the curriculum" guided Meikle's efforts. He, along with many other medical educators, knew that if one wanted to make a difference in the way medicine was taught, one needed to change the way it was evaluated. Meikle has consistently held the vision of direct observation of clinical skills as a critical element in the education of medical students, even when his Board of Directors, which included a number of physicians, expressed uncertainty about the efficacy of performance-based assessment.

The next Macy support was received by Abrahamson at USC. In 1987 at Asilomar, California, he led the effort to win the support of medical school deans with another multiple-station, hands-on demonstration using standardized patient cases from SIU. This time the demonstration was solely for deans of the western regional medical schools. Following the success at Asilomar, Barrows modeled similar demonstrations for deans at medical schools in the other three regions of the country over the next several years. Out of these five Macy-funded participatory demonstrations, involving ninety-one medical schools, came enthusiastic interest in standardized patient examinations as a

potential, viable solution to the evaluation of medical students' clinical competency. It came from the majority of medical schools in the United States; and it came from the highest academic level, from medical school deans, whose written responses to these demonstrations were sent to the Macy Foundation as letters requesting financial support to explore performance-based assessment at their own institutions.

Meikle wanted to respond without delay to the deans' interest, but he was still dealing with some members on his own board who were "very unconvinced" because they felt that medical students would reject these "surrogates who are pretending." He contacted Mt. Sinai, a medical school in close physical proximity to the Macy Foundation in New York City, to see if the dean would be interested in starting a standardized patient program. Meikle's idea was to provide a firsthand experience for his board of trustees, similar to the demonstrations that had proven to be so convincing to the medical school deans. By 1990, as a result of a burgeoning standardized patient program, the Morchand Center for Clinical Assessment was built at Mt. Sinai. Meikle then persuaded the trustees of the Macy Foundation to hold one of their meetings at the new center. "That," he recalled, "was the way I convinced, particularly the physicians and educators on the Macy board, to set up the consortia."[46]

In 1991 and 1992, the Macy Foundation awarded grants to support six consortia with the expressed purpose of building cooperation among schools as each consortium developed a capability for designing and utilizing a standardized patient Clinical Practice Examination (CPX) for their students. The Macy Foundation also had the foresight to establish an umbrella organization which was responsible for regularly bringing together the leaders from the six consortia in order to share information and to ensure that the educational impact of consortia activities would be measured and documented. That organization, EMPAC (Educational Impact of Macy Project Affiliated Consortia), was established at the SIU School of Medicine under the direction of Howard Barrows. Along with the twenty-eight medical

Institutions Participating in Consortia, 1996

Consortium contact is italicized
Educational impact of Macy Project Affiliated Consortia (EMPAC)
coordinated by *Southern Illinois University School of Medicine*

Josiah Macy, Jr. Foundation-Sponsored Consortia (28 schools)

Gulf Coast Regional Consortium for Assessment of Performance: *University of Texas at Galveston*, University of Texas at Houston, Baylor College

Metropolitan New York Center for Clinical Competence: *Mount Sinai School of Medicine*, New York Medical College, Albert Einstein College of Medicine, Cornell University, New York University, State University of New York (SUNY) at Brooklyn, SUNY at Stonybrook, Columbia College of Physicians and Surgeons

North Carolina Medical Schools Consortium: *University of North Carolina*, Bowman Gray, Duke University, East Carolina University

Northwest Consortium for Assessment of Clinical Performance: *University of Washington*, University of Nevada, Oregon Health Sciences University, University of Colorado

Southern California Consortium for Assessment of Clinical Competency: *University of Southern California*; University of California, Irvine; University of California, Los Angeles; University of California, San Diego; Loma Linda University

Upstate New York Clinical Competency Center: *Albany Medical College*, SUNY at Buffalo, SUNY Health Sciences Center at Syracuse, University of the State of New York Regents College Nursing Program

Independent Consortia (13 schools)

Chicago Clinical Skills Consortium: *University of Illinois at Chicago*, Finch University of Health Sciences/Chicago Medical School, Loyola University, Northwestern University, University of Chicago, Rush Medical College

New England Consortium: *University of Massachusetts*, Boston University, Harvard University, Tufts University, Brown University, Dartmouth University, University of Connecticut

schools involved in the Macy Consortia,[47] two independent consortia were formed: the New England Consortium by Stillman in the 1980s[48] and, most recently, the Chicago Clinical Skills Consortium by the psychometrician and medical educator Reed G. Williams. Schools in these eight consortia, along with several other individual schools, represent almost one third of American medical schools that have been or are currently engaged in the development of a required performance-based clinical assessment of their students.[49]

Integrating the Wisdom of the Staff

The Association of American Medical Colleges (AAMC) and the American Medical Association (AMA) were responsible for metaphorically digging the post-hole for the rod of the caduceus through their interest and their activities in supporting the firm establishment of standardized patient methodology into medical school curricula. First came the criticisms and recommendations for American medical education in the 1984 report *Physicians for the Twenty-First Century: Report of the Panel on the General Professional Education of the Physician and College Preparation for Medicine* (commonly known as the GPEP Report).[50] Then, the AMA Liaison Committee on Medical Education (LCME) formally incorporated into its accreditation standards the directive requiring that each medical school "develop a system of assessment which assures that students have acquired and can demonstrate on direct observation the core clinical skills and behaviors needed in subsequent medical training."[51] Finally, two reports were published by the AAMC, which sponsored the 1992 "Consensus Conference on the Use of Standardized Patients in the Teaching and Evaluation of Clinical Skills."[52] As a consequence, the interest in standardized patients as a means of assessing clinical competency grew, not just in the rarified air of the ivory tower academic or the medical education theoretician and researcher, but, more importantly, at the grassroots level of individual medical schools. A 1993 AAMC survey sent to all 142 North American medical schools requested information on use of standardized patients. Of the 138 schools responding, 111 reported using SPs for both teaching and evaluation and thirty-nine of those schools were using standardized patients in a comprehensive examination to assess clinical skills before graduation.[53]

Weaving the Fabric: Standardized Patients and Performance Assessment

The major focus of medical education research involving standardized patients from 1984 to the present has been performance assessment. It is the emphasis on performance assessment, in its many variations, that has given face validity to the use of standardized patients and encouraged the wide spread acceptance of this educational innovation. Because of the emphasis on evaluation during this period, there has been a shift away from all previously used terminology, in preference for the almost exclusive use of the expression *standardized patient*. Though one often still does hear the term *simulated patient*, it is primarily used to refer to the SP as a more generic teaching and learning tool, rather than exclusively as one for evaluation.

It is perhaps also valuable to clarify the differences between the two types of performance-based assessments: the Objective Structured Clinical Examination (OSCE) and the CPX. The OSCE was introduced in Scotland in the mid-1970s by

Ronald Harden of the University of Dundee.[54] In the intervening years, the OSCE has been refined by Harden's Scottish colleague Ian Hart, currently on the Faculty of Medicine at the University of Ottawa. Hart has been responsible for the introduction of standardized patients and the OSCE into many specialty examinations of the Royal College of Canada.

The OSCE tests specifically defined single skills. OSCE station instructions might direct the student to perform a chest exam, take a blood pressure on a real patient, take a substance abuse history from a standardized patient, start an IV on a plastic model arm, read an X-ray, or interpret lab results. In Barrows's words, the OSCE assesses the skills of the examinees by "taking a biopsy" of their clinical ability. The OSCE generally relies heavily on real patients. It may or may not incorporate standardized patients. Station length is usually short (four to ten minutes), depending on the complexity of the individual tasks comprising the exam. And in an OSCE, it is most often faculty who observe and rate the student's performance.

On the other hand, the CPX is designed to give students the opportunity to perform with a standardized patient as if they were practicing clinicians in an actual encounter. Students must rely on their own clinical judgment, responding in whatever way seems appropriate based on the patient complaint. The CPX is designed to assess the whole clinical process including history-taking, appropriate focused physical examination, patient education, and interpersonal skills. CPX stations are generally a minimum of fifteen to twenty minutes in length. The cases are portrayed by carefully trained standardized patients. And in a CPX, it is the standardized patient who records the examinee's behavior on a checklist after each encounter. Barrows summarized the differences succinctly:

> This [CPX] format focuses on the student's ability to use all clinical skills and to orchestrate them in an appropriate way with appropriate priorities depending upon the problem that was presented.
>
> The OSCE can determine whether a student is capable of carrying out a particular skill, but does not determine whether the student will use that skill with an appropriate problem.[55]

Since there has been a tendency to call all multiple-station, performance-based exams OSCEs, Meikle convinced Barrows of the importance of coming up with a name that distinguished the OSCE from the type of clinical exam that Barrows was engaged in at SIU. It was at Meikle's urging that Barrows searched for a name: "When you hear it you know what it is. It's a Clinical Practice Examination. You're examining the student in a clinical practice situation—complete interviews with a series of patients, like in a practice."[56]

After Barrows's first multiple-station standardized patient demonstration at SIU in October 1984, the ten invited deans empowered another of the conference participants, Stephen Abrahamson, to convene a committee to further the development and medical school use, of this type of performance assessment, and to find funding to support that effort. This task force, known as Project Mousetrap, was ahead of its time in 1985.

Two activities were explored by Project Mousetrap: "The Snake Oil Project"[57]—"traveling road shows to sell schools on the use of standardized patients in the assessment of student clinical performance"—and "Building a Better Mousetrap"—the

Number of Articles Published on Simulated/Standardized Patients, 1966–1996

MEDLINE and PSYC INFO	Citations Found
1966–1976	5
1977–1986	33
1987–1996	149

establishment of cooperation among several schools to determine graduation objectives, to design examination blueprints, and to develop quality cases, psychometrically sound checklists, and standardized patient training protocols that would assure test reliability. According to Abrahamson, "The Task Force agreed that it was really interested in the Better Mousetrap and turned its attention to the development of this project."[58] Ironically, though no funding was found before the group disbanded, a few years later both of the concerns of Project Mousetrap became the missions of a combination of other organizations: the Macy Foundation through its support of the "travelling road shows" for deans and through the establishment of CPX-based consortia; and the National Board of Medical Examiners through its ongoing valiant efforts to establish a performance-based, clinical-competency examination as part of Step II of the United States Medical Licensure Examination (USMLE).

Besides Abrahamson, Barrows, and Stillman, and representation from the AAMC, the committee consisted of a number of psychometricians: Geoffrey Norman of the Department of Clinical Epidemiology and Biostatistics at McMaster; David B. Swanson of the American Board of Internal Medicine (ABIM); Dax Taylor, Vice President for Test Development at the National Board of Medical Examiners (NBME); and Reed Williams of the Department of Medical Education at SIU. The psychometric aspects of performance-based examinations were already becoming the principal focus of research. The major measurement concerns were the usual ones: reliability and reproducibility of test results, validity, feasibility, scoring, and reporting. However, the unique demands of this new test modality–using multiple standardized patients who perform the same case within a site or across sites; multiple standardized patient raters using the same checklist; number and length of cases needed for a reliable measure; criteria to determine "clinical competence"; and many more such concerns–challenged the creative thinking of psychometricians, most of whom had previously worked in the more cognitively-pure area of multiple-choice examinations.

By the end of 1985, it was clear that the climate among the foundations that traditionally fund medical education projects was not quite ripe for the ambitious consortial nature of Project Mousetrap. However, under Abrahamson's leadership, Project Mousetrap did inspire a number of important individual efforts from among members of the task force that, in turn, spawned research by other investigators beyond the group, finally galvanizing critical financial support from some of the very organizations who failed to see the landmark nature of what the Better Mousetrap group had attempted to accomplish. These generative research studies have contributed significantly to the

improvement of CPX psychometrics and to the dissemination of the clinical practice examination across a broad range of medical schools.

A decade after Barrows and Williams mounted the first clinical practice examination at SIU in 1985,[59] two key review articles finally gave legitimacy to large-scale standardized patient-based examinations: "Assessment of Clinical Skills with Standardized Patients: State of the Art" by Cees van der Vleuten and David B. Swanson (a review of psychometric research)[60] and "Use of Standardized Patients in Clinical Assessments: Recent Developments and Measurement Findings" by Nu Viet Vu and Barrows.[61] With the publication of these reviews focusing on the psychometric aspects of large-scale clinical assessments using standardized patients, it was no longer necessary to justify the essential reliability, validity, and feasibility of these types of tests. One no longer had to apologize to skeptics of standardized patient-based examinations, one merely had to refer to these reviews.

During the same time, Paula Stillman and David Swanson teamed up, working together for about six years with funding from the American Board of Internal Medicine, which was searching for a better performance-based method of assessment for certification than its Clinical Evaluation Exercise (CEX), which involved a single faculty observation of a resident with a patient during the first postgraduate year of training. They completed the first-of-its-kind, multi-institutional study of the clinical competence of internal medicine residents using standardized patients,[62] and eventually established a CPX-type examination for fourth-year students at the University of Massachusetts and several other medical schools in the New England area.[63]

Simultaneous with these efforts came the National Board of Medical Examiners' Standardized Patient Project exploring a "high stakes" clinical assessment component for licensure, the Macy Foundation support of medical school consortia, and the Educational Council for Foreign Medical Graduates' (ECFMG) pilot project to assess the clinical competence of graduates of medical schools outside of North America who were in U.S. residency programs.[64] All of these efforts were aimed at finding a viable method to accurately assess clinical competence, the consequence of which was the further development, refinement, and ultimate acceptance of standardized patients as that vehicle.

One of the other threads in this narrative is Daniel J. Klass, the director of the NBME Standardized Patient Project. His coming to the National Board of Medical Examiners interweaves with a number of other threads in the history of the growing use of standardized patients. In the early 1980s, Klass was the Associate Dean for Medical Education at the University of Manitoba. He, like everyone else who is required to write "dean's letters" of reference for students embarking on post-graduate work, was dependent upon written evaluations from faculty who often disagreed about the quality of the student in question. "I started looking into the literature on clinical evaluation and found very little to go on," he said. "The literature was depressing. Whatever you saw said exactly the same thing, clinical evaluation was not very good."[65]

Around the same time, a nurse by the name of Robyn Tamblyn moved to Manitoba. According to Klass: "She came into my office wondering if there was any work that she could get in the Department

of Medical Education and I didn't know who she was. I'd never heard of Robyn Tamblyn. I'd never heard of Howard Barrows. I found out pretty quickly."[66]

Robyn Tamblyn, of course, had been one of the first simulated patients trained by Barrows at McMaster. Her introduction to the world of standardized patients came while she was working with him as part of a neurological patient care team. When one of Barrows's simulated patients became too pregnant to perform at a meeting of the Association of Neurological Professors, Barrows convinced Tamblyn, who had never heard about the technique before, to become an SP. According to Barrows: "She became one of the best SPs I ever worked with and in a very short while became a trainer of SPs and set up the first organized SP program at Mac. That means that when she presented herself to Klass, it was not just as an SP, but as an SP trainer and program director."[67]

Tamblyn encouraged Klass to think about initiating a standardized patient program and introduced him to Barrows at the next AAMC meeting. Klass visited SIU shortly thereafter, went through Barrows's classic hands-on experience with a standardized patient, and, promptly decided to do a two-site CPX project together with Barrows. "Out of the blue, [we] created a standardized patient program that piggy-backed onto Howard's, in that we started by just saying,'We're going to do an exam with SIU.'"[68]

SIU initiated the project by supplying the cases, the faculty demonstrations, and the expertise. Within a few months, Klass and Tamblyn had mounted an examination for all the students at the University of Manitoba using standardized patients who had been trained locally. Out of the two-school examination experience, between 1985 and 1987, came a number of interesting findings regarding portability of cases and standardization of SP performances across sites.[69]

Klass's early connection with Barrows was significant in influencing the work he was about to begin at the National Board. Barrows, he said, "did with us what we have since tried to model with many other schools. The best way to learn how to do standardized patients is to do it along side of someone who has already done it before. It's [the] apprenticeship system."[70]

The NBME has never worked in isolation. It has always seen the success of its licensing mission dependent upon collaboration, formal or informal, with its support coming from the State Federation of Medical Boards, the medical schools, and their faculty. This underpinning continues to guide the philosophy of the Standardized Patient Project in its work with medical schools, as well as with other organizations exploring the same territory.

From the beginning of his presidency at Macy, Meikle stayed in conversation with the NBME, whose own issues helped him define the next steps for the Macy Foundation. "Basically what I thought they [NBME] were concerned about was how they were going to test 16,000 students. And I thought this was a legitimate issue. So it seemed to me, the question was:'What could schools do with [a] relatively minimal amount of money? And what could they do by *sharing*?' And that was the consortial concept."[71]

As it has evolved, the success of the Standardized Patient Project has depended, in some measure, on the very existence of the Macy consortia. Over the last five years, the twenty-eight Macy schools have provided the National Board

with a majority of its sites for piloting everything from logistics, to trainer education, to case performance. The Macy Foundation has begun to establish grassroots acceptance of standardized patient examinations at the medical school level. In fact, the dependence of faculty on the data from such examinations, which have been in place for several years, has laid the groundwork so necessary for the NBME to function. In Klass's words: "A standardized process that can be used as part of licensure across the whole country will only work if standardized patients become part of the culture of medical schools using standardized patients for their own purposes, not to meet the needs of licensure, but for their own evaluative purposes, for their own teaching purposes."[72]

There is an ongoing struggle to integrate the focus of the medical schools—which is to educate its students to the highest standards of excellence—and the concern of the National Board to establish "minimal national standards of clinical competence" for licensure. But, in many ways, there is a recognition by both parties that each needs the other. In order to maintain the existence of the standardized patient teaching and assessment programs at the medical school level, many schools need the pressure of the NBME interest in the clinical practice examination. This is particularly important in the budgetary atmosphere of the 1990s, when what happens in medical education is often defined by "fiscal exigency." In such a climate, no matter how powerful the data, an innovation that is just becoming established can easily be cut from the medical school budget. On the other hand, the NBME needs the continuing fertile ground of grassroots, standardized patient programs because it is the medical schools that likely will provide the professional sites where the clinical competency licensure examination will be delivered when it is ready. These mutual needs are bringing integration to traditionally competing forces. It is the wisdom of the serpents—the essence of the caduceus.

Separate but interwoven with the NBME Standardized Patient Project is a similar effort by the Educational Council for Foreign Medical Graduates (ECFMG). Here, again, a number of threads have come together. Alton I. Sutnick, former dean of the Medical College of Pennsylvania (MCP), was one of the original deans invited to the Macy/SIU invitational conference and demonstration in 1984. Abrahamson remembered Sutnick's response, more than any one else's, to his first experiences with standardized patients at that demonstration: "Each time he came out of a case, his eyes were as big as saucers because he could see the power of this thing."[73] Sutnick's own remembrance of that experience corroborated Abrahamson's: "Boy, was I impressed! I thought it would be something like a regular role playing, but it was so much more. I could really see what he [Barrows] was talking about so enthusiastically. He had said: 'You'll never appreciate it until you experience it yourself.' . . . It was during that day that I saw that this really did have the potential for assessment, and that it ought to be promoted."[74]

Within a short time, Sutnick invited Paula Stillman to speak with his faculty at MCP, found clinic space, and appointed the team that established the first standardized patient program in Philadelphia.

A couple of years later, Robert Petersdorf, then president of the AAMC, invited Sutnick to sit with him in one of

the two AAMC seats on the ECFMG board of trustees. ECFMG, whose mission is to certify foreign medical graduates for practice in the United States, was an organization with two attractions for Sutnick, working with internationally trained physicians and exploring the assessment possibilities of standardized patients. Sutnick remembered:

> The ECFMG board had already begun looking into how to test clinical skills with some studies [that had been] done in the mid-'80s.[75] These involved taking histories and doing physical examinations on real people. There were a lot of psychometric problems, so that the board wasn't ready to accept that direction. They appointed a new committee to review [that work] and decide what to do.[76]

Because of his experience at MCP, Sutnick was asked to serve on that committee. Through a series of circumstances, Sutnick recalled, "I found myself in the role of planning and making recommendations on what ECFMG should do." Within a short period of time, the new president of ECFMG asked Sutnick if he might be interested in being a candidate for vice president. Years before, Sutnick had enjoyed working collaboratively with basic scientists from other countries and had been interested in the concerns of foreign medical graduates since his work in the 1960s with the Philadelphia County Medical Society, where he provided "hospitality for foreign physicians, including foreign medical graduates who were taking residencies in Philadelphia." "Little did I know," he said, "that some 25 years in the future I would become vice president of ECFMG."[77] Sutnick left MCP to take this new position in 1989.

As vice president, he became responsible for clinical skills assessment. The first thing he did was bring together a distinguished group of educators who had been working with standardized patient-based performance assessment, including Howard Barrows, Paula Stillman, Ian Hart, and two psychometricians—Miriam Friedman, who had been consulting with ECFMG from the University of New Mexico, and John J. Norcini of the American Board of Internal Medicine.

Because of the communication through medical education literature and the cross-fertilization taking place directly among the principal players, the various approaches to standardized patient-based performance assessment had essentially converged. According to Sutnick, the ECFMG clinical assessment committee "suggested that Stillman be the active person working with us. She had developed a system, a process. She had a group of people who could contribute as collaborators. And that was crucial."[78]

Stillman remembered how quickly the committee was able to get the pilot ready: "We set up four centers around the country. And I used cases that I knew. We trained patients at each of the sites. And it was done. . . . We put the exam together in a year."[79] So between 1990–1991, two pilot studies were mounted by the ECFMG using the same standardized patient cases that had been developed in New England for the fourth-year medical students' clinical examination.[80]

A race to be the first to adopt a high-stakes, large-scale standardized patient clinical competency examination for licensure came to the forefront in the early 1990s. The Medical Council of Canada (MCC), under the direction of Richard K. Reznick, was exploring the use of standardized patients for a national OSCE-type certification examination. Reznick's

interest in standardized patients grew during the year he spent working with Barrows at SIU while earning a master's degree in education. In 1993, under Reznick's direction, the MCC became the first organization to implement a national standardized patient-based performance assessment as a required part of the licensure examination.[81] In 1994, the ECFMG authorized the Clinical Skills Assessment as part of its certification process.[82] And in 1995, the NBME endorsed the use of a standardized patient examination as part of USMLE Step II with implementation to be within the next four to seven years.[83]

Along with the growing use of standardized patients in North America, there has been a corresponding interest in standardized patients internationally. In 1985, Ian Hart and Ronald Harden organized the Ottawa Conference on Assessing Clinical Competence. This biannual forum has become "the largest regularly held international conference on medical education."[84] Over the years, standardized patients have gradually been incorporated into the curricula of other medical schools around the world through the important work of such individuals as Ronald Harden in Scotland, David Newble in Australia, Cees P.M. van der Vleuten in The Netherlands, and Nu Viet Vu, who recently moved from SIU to Switzerland. Paula Stillman introduced the standardized patient to China; at the same time, the ECFMG has shown an interest in transporting the standardized patient methodology to a number of other countries with the dream of ultimately establishing global clinical standards. Towards that effort, the ECFMG, along with the World Health Organization, has assisted Israel, Spain, Russia, the Ukraine, and Brazil to mount standardized patient examinations that are designed for each of their country's needs.[85] In little more than three decades, the use of the standardized patient in medical education has grown dramatically from its modest beginnings in California as a pedagogical novelty to the global phenomenon that it is today.

Conclusion

Standardized patient methodology is no longer in question. Yet, in our rush to quantify and establish its efficacy, a new question emerges. Have we not forgotten how much potential there is for the standardized patient in other areas—those wings on the caduceus? Assuredly, there is much left to be done in psychometrics, especially in the area of validity. Are we, in truth, assessing what we think we are—clinical competence? Is the design of the checklist, are all those details, really what we care about, or is there some other way to look at this? Now as much as ever, our creative instincts are called for.

As managed care is in ascendance, so might there be even more creative ways to use the standardized patient. The "patient instructor" might become a necessity rather than a luxury—and standardized patients might be even more extensively needed for clinical learning and self-assessment as the pool of teaching faculty dwindles. And what about the practicing physician, or the one who has lost his license to practice? Might not the standardized patient be able to support the physician in new learning in the way of the Bedside Clinics or, in some way, make it possible for the physician-in-trouble to relearn?

Epilogue

In looking back on any human endeavor, it is always interesting to see how diverse are

the motivations that shape that history. Altruism and egotism entwined, create the path, inspire the wisdom that has shaped the movement towards the way we are now teaching and testing the clinical skills of the young people who will be our future physicians. This is the standardized patient, a single educational innovation that had as much chance, or more, of not-being as being. It is the thread that held the inspiration until all was ready for the weaving—the golden winged rod entwined with oppositional energy that symbolizes the integration around which so much else has been explored and discovered. May that golden rod, now firmly planted, continue to inspire winged ideals in the midst of the inevitable conflict of opinions that will create the fertile soil for sustaining educational efforts as the search goes on for a better way to support the healers of today—and nurture those of tomorrow.

♦

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Sim One—A Patient Simulator Ahead of Its Time

Stephen Abrahamson

Some Historical Notes

Imagine, if you will, an artificial patient which might be used to train health-care personnel in clinical maneuvers which are potentially threatening to real patients and therefore difficult to teach. With today's technology, particularly state-of-the-art computers, it may not be that difficult to visualize such an apparatus: a simulated human being, capable of real-time, lifelike reactions to procedures done by the health-care trainee.

Such a device was designed, produced, tested, and then used as long ago as 1967! Its inventors called it "Sim One" in optimistic anticipation of a long line of similar simulators to be used in teaching health-care students those clinical skills which involve potential threat to the patient on whom the skills must otherwise be learned. At the time of its "debut" on March 17, 1967, Sim One was quite lifelike in appearance, having a plastic skin which resembled that of a real (Caucasian) human being in color and texture. He (it was a male) had the configuration of a patient lying on an operating-room table with (1) his left arm extended and fitted with an intravenous portal ready for intravenous injection; (2) his right arm fitted with blood-pressure cuff; and (3) his chest having a stethoscope taped over the approximate location of his heart. Sim One breathed, had a heart beat, temporal and carotid pulses (all synchronized), and blood pressure. He was able to open and close his mouth, blink his eyes, and respond to four intravenously administered drugs and two gases (oxygen and nitrous oxide) administered through mask or tube.

The physiologic responses to what was done to Sim One were in real time and occurred automatically as part of the computerized program. It was possible to perform the entire maneuver of endotracheal intubation and administration of anesthesia in exactly the manner in which it was done in the operating room: administration of oxygen through mask and bag, injection of sodium pentothal, injection of succinylcholine, insertion of an endotracheal tube using a laryngoscope, and administration of oxygen and nitrous oxide through pressure on the reservoir bag, each action responded to by appropriate physiologic responses dictated by the computer which controlled the system.

How this device became a reality is a story which provides one more illustration of Abrahamson's Formula for Success: Dumb Luck! One day in 1964, Tullio Ronzoni, an engineer at Aerojet-General's Von Karman Center at Azusa, California, walked into the office where I was Director of the Division of Research in Medical Education at the University of Southern

California (USC) School of Medicine and asked a simple question. Ronzoni at that time was also a member of a committee of the Los Angeles Chamber of Commerce charged with finding nondefense activities for the aerospace industry, which seemed in danger of losing government contracts because of the perceived (or should we say "misperceived"?) decline in "defense" spending. His question was indeed simple: "How can we use today's computer technology in medical education?" I was immediately put off and thought of Ronzoni as one more "nut." I was on the point of recommending that he go see someone else when Ronzoni said, "If you can't help me, I'm off to UCLA."

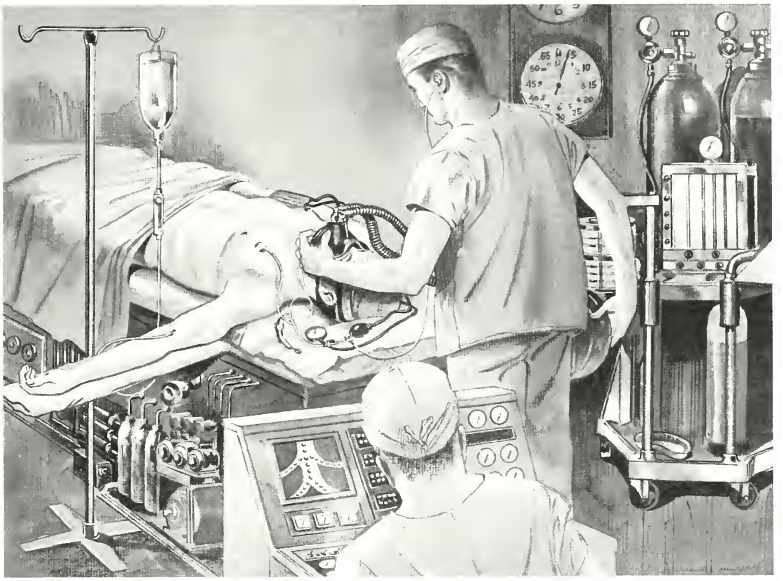
Those words prompted me to stifle the urge to "send him on," and a dialog was opened. Perceiving that Ronzoni was thinking of something that truly capitalized on the power of the computer in a manner similar to that of the Link Trainer used to teach pilots how to fly, I proposed that a simulation system be devised that would provide all of the meters, dials, and gauges monitored by an anesthesiologist during surgery along with computer control so that as the students responded to the information provided by the meters, dials, and gauges, the system would provide accurate responses and thus engage the trainee in a simulated training exercise.

Ronzoni liked the concept and then I confessed that I had never been inside an operating room except when unconscious during my own hip surgery and suggested consulting J. Samuel Denson, who was Chief of Anesthesiology at the Los Angeles County General Hospital. Denson, in turn, was excited by the concept, and the three of us then met with several engineers at Aerojet-General, most notably A. Paul Clark and Leonard Taback. During the course of one of several luncheon meetings, someone suggested building the whole body, not just the meters, dials, and gauges, and in that way expanding the simulation to something resembling much more closely the actual training situation.

After determining that the state of the art of the needed materials and technology (e.g., plastics, computer, animation) was indeed adequate for the demands to be met, the team went to work on system requirements and specifications. Within a month or so, the required system was described in a proposal with an artist's drawing depicting the system—by this time called "Sim One." All that was needed then was financial support.

The search for funds in 1964 and 1965 took the team to any number of bureaus, divisions, and sections of the federal government, including those in the Department of Health, Education, and Welfare (HEW), the Department of Defense, and the Public Health Service. None of these visits resulted in anything more than comments like "What a great idea" followed by "We don't have money for great ideas." On returning to Los Angeles, I sat down and wrote a proposal and mailed it to the United States Office of Education's Cooperative Research Project for their consideration. The "team" received a favorable response and a grant of $272,000. In the summer of 1965, the date of the grant, that was indeed a substantial amount of money.

It is interesting to note the circumstances surrounding that grant. Years later I met a man who had been a member of the committee which reviewed our proposal. He told me that the committee voted to reject the proposal because someone at the meeting said, "The



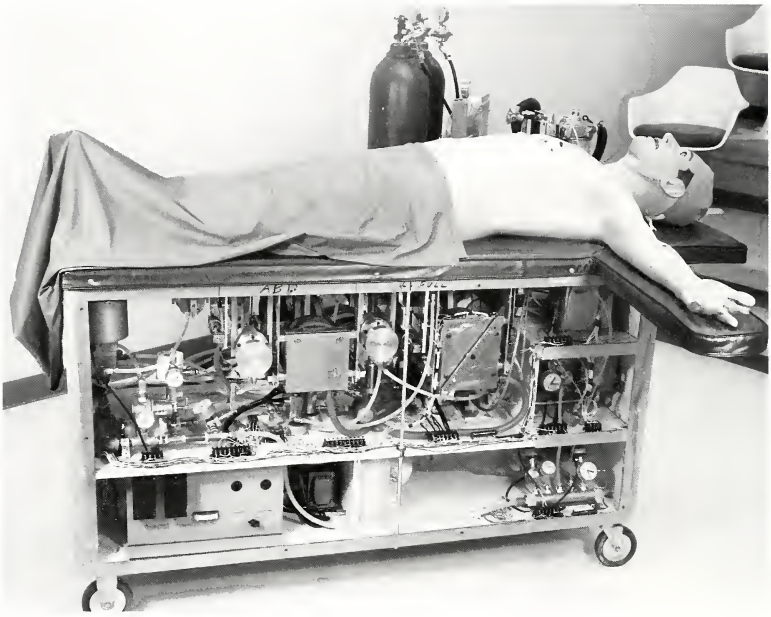
Original artist's drawing which accompanied the grant proposal submitted to the United States Office of Education. In the summer of 1965, the proposal resulted in an award of $272,000 to Stephen Abrahamson, Director of the Division of Research in Medical Education of the University of Southern California School of Medicine.

damned NIH has all of the money; they can fund this thing." At that point this man told me that he stood up and said, "The NIH will never fund something as innovative as this; we should do it." And thus, Sim One, already conceived, was now in gestation.

Engineering Notes

The project was designed to demonstrate the feasibility of simulating a human being for purposes of training physicians (or other health-care providers) to perform certain clinical tasks involved in health care and to show the effectiveness of using such a simulator in clinical training. The inventors chose the complex task of endotracheal intubation and induction of anesthesia because it is a demanding procedure requiring knowledge and judgment in addition to psychomotor skills. Sim One, therefore, was constructed to "behave" and "respond" as a real human being undergoing endotracheal intubation and induction of anesthesia.

The first step was to analyze physiologic and pharmacologic data to serve as the guide for the design of both the manikin



Sim One lying on his operating table. Mechanisms underneath controlled many actions, including breathing, measurement of intravenous injections, jaw movement, blinking of eyes, "bucking" when anesthesia level gets too low, and heart beat.

and the computer programs. Denson provided the necessary data based on his experience and his knowledge of the basic medical sciences of physiology, pharmacology, anatomy, and pathology. Raw data then had to be reviewed and refined into manikin specifications and computer programs by the engineers. The resulting system, Sim One, was expected to simulate the following procedures described in *Medical Engineering*:

Oxygen is administered through mask to the patient for a period of 5 minutes in order to raise the oxygen level in the tissues and thus provide an extra margin of safety during the time in which the patient might go without oxygen during the next stages of the maneuver. Sodium pentothal is administered intravenously, which renders the patient unconscious. Succinylcholine is injected, which produces paralysis of skeletal muscles and indeed causes the patient to stop breathing. The anesthesiologist then quickly slips off the

mask and inserts the airway tube into the trachea, sealing it inside the walls of the trachea by inflating the balloon-like rubber cuff of the tube. Through this tube, connected to the anesthesia machine, the anesthesiologist then administers oxygen and nitrous oxide by squeezing the inflated reservoir bag. During all of this activity, Sim One's computer registers all of the anesthesiologist's actions and the agents administered and dictates the appropriate physiologic responses. At any time, the instructor has the option of "overriding" the physiologic program in order to produce such problem situations as cardiac arrest, abnormally increased or decreased blood pressure, left or right block of the bronchus, increased or decreased breathing rate, cardiac arrhythmia, ventricular fibrillation, increased jaw tension and vomiting![1]

Not only was Sim One able to simulate all of the physiologic "behavior" of a real human being, he also had anatomic authenticity with the following all included. Inside the mouth were the normal structures: teeth, tongue, palate, epiglottis, aryepiglottic fold, esophageal opening, and vocal cords visible when the laryngoscope was inserted. Breathing involved two movements in the body: rib-cage expansion of the chest wall and diaphragmatic shift toward the abdomen.

The system consisted of five major components: the manikin (constructed by the Sierra Engineering Company), the computer (Aerojet-General's general-purpose hybrid computer), a real anesthesia machine (Ohio-Heidbrink Model B3303), an instructor's console, and an interface unit.[2]

The project was started in the summer of 1965, with actual construction underway by January, 1966. The system was available for testing and refinement in January, 1967. Actual studies of its effectiveness were started during the summer of 1967.

Introduction of Sim One

Sim One made its official "debut" at Columbia University at the annual meeting of the Professors of Anesthesiology on March 17, 1967. Denson and I made the presentation, and two incidents occurred during the "unveiling" of Sim One which may be of some interest. A special motion-picture film was deemed necessary to describe the simulator to any audience since slides or photographs could never convey the "behavior" of the device. Thus, our presentation involved narration to accompany this silent motion-picture film of Sim One for the audience of Professors of Anesthesiology. Denson narrated the first half, which showed the entire clinical maneuver of endotracheal intubation and induction of anesthesia performed by him on Sim One. At one point, the audience was heard to chuckle, causing both of us to fear the worst: somehow or other, there was something that did not ring true to this critical audience. At lunch immediately following the presentation, however, Denson and I learned what had caused the laughter. Apparently, these professors of anesthesiology had found themselves holding their breath during the time that Sim One's breathing had been stopped by the administration of succinylcholine and then had expelled the air when Denson had started the flow of oxygen. The simultaneous expulsion of air by the members of the audience apparently caused them all to laugh! The explanation was simple enough. During the filming, Denson had to perform all the steps very slowly in order for the film to show the processes

clearly. Thus, although the film appeared to be showing the maneuver in real time, much more time was taken by Denson than a competent anesthesiologist would require in an operating room. The point of relating this anecdote is simply a confirmation of the authenticity of the simulation.

The other incident occurred at a luncheon table after the presentation. I was asked how much this simulation system had cost, the questioner trying—apparently—to determine if the simulator would be cost-effective. When I reported that the grant from the United States Office of Education had been $272,000, my questioner (a professor of anesthesiology at a medical school) replied, "It doesn't cost nearly so much to train them now," suggesting that students—including residents—could be trained on real (charity) patients more cheaply than on a simulator. Denson and I, of course, believed that using such a patient simulator would save these real patients from potential harm and/or discomfort. The question of "cost-effectiveness" was to become an important issue for Sim One's future.

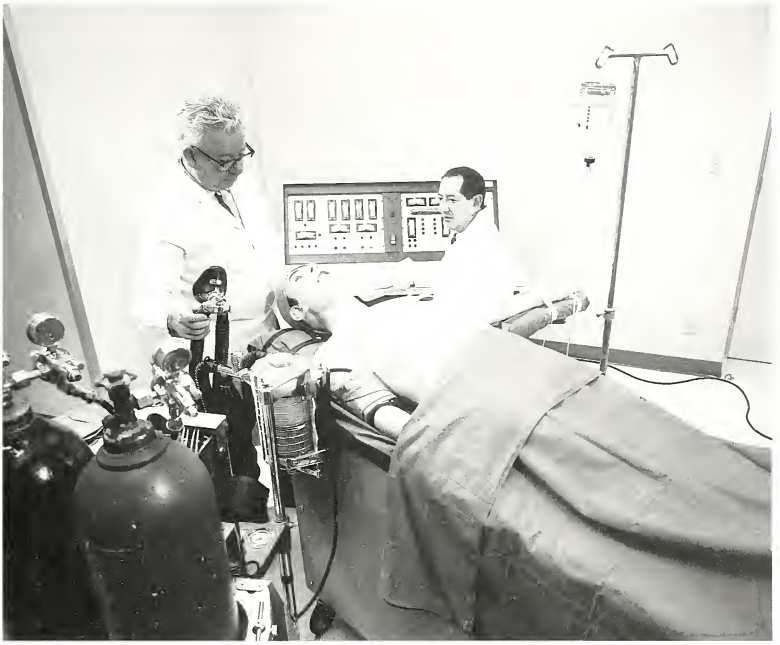
The First Study

The effectiveness of Sim One was studied using twelve new anesthesiology residents at the Los Angeles County General Hospital. After two residents were eliminated because of extensive prior experience in intubation, the remaining ten were "paired" for study purposes: five receiving training on Sim One at Aerojet-General's Von Karman Center, the other five getting their training experience in the operating room, without the benefit of "training runs" on Sim One. The hypothesis of the study was that the residents trained on Sim One would arrive at predetermined levels of competence (1) in less elapsed time from when they started their residency and (2) with fewer trials in the operating room than their counterparts. The major source of data was expert review of anesthesia charts which included complete records of all anesthesiology procedures during surgery. More than twelve hundred charts were reviewed by experts who did not know which charts belonged to Sim One–trained residents. Data confirmed the hypothesis: the simulator-trained residents arrived at criterion levels of performance in significantly fewer operating-room trials and in significantly fewer elapsed days from the start of training.[3]

More specifically, the study showed that "elapsed time in days from the beginning of the residency to completion of nine out of ten consecutive professionally competent intubations in live patients averaged 45.6 days for the simulator group and 77 days for the control group. To achieve this same level of competence, the simulator group required only 30 attempted (actual) intubations in the operating room, compared with 60 for the control group."[4] In addition, those residents trained on Sim One were observed making half the number of errors in the operating room of those made by the control group.

Follow-Up Work

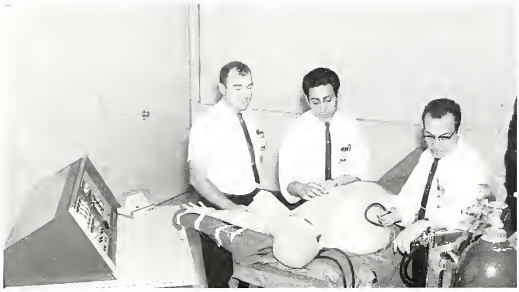
The immediate reaction to Sim One was a flurry of high-profile attention, including articles in *Life*, *Time*, and *Newsweek*, and an interview of me on *Walter Cronkite's CBS Evening News*. HEW officials not only took a great interest in the project but offered to put together a "package" of subsidy for continued development from some HEW agencies and the United States Office of Education. They further suggested that Denson and I, as the principal investiga-



J. Samuel Denson, Chief of Anesthesiology at the Los Angeles County General Hospital, stands at Sim One's head ready to place the mask over Sim One's face to administer oxygen from the anesthesia machine. Abrahamson sits at the instructor's console ready to monitor the procedure and to introduce problems such as increase or decrease in blood pressure, increase or decrease in heart rate, heart arrhythmia, heart arrest, "bucking," or vomiting.

tors on the original project, develop not just another study but comprehensive plans for the future. Together with Ronzoni, we laid out plans for a "Simulation Center" with projected development of a number of simulators, each dedicated to a different set of clinical tasks. The plan also included the simulation of a "complete" patient as the culmination of the first seven years of work. Ronzoni even went so far as to identify a building in which the center might be housed.

But such was not to be. With the Viet Nam War claiming more and more of the national budget, the costs were declared too high by the funding agencies, no one of which would have been able to claim the project as its own. Instead, we were asked in 1969 by the newly established National



Three Aerojet-General engineers check out Sim One's functions: A. Paul Clark, Henry Perez, and Leonard Taback.

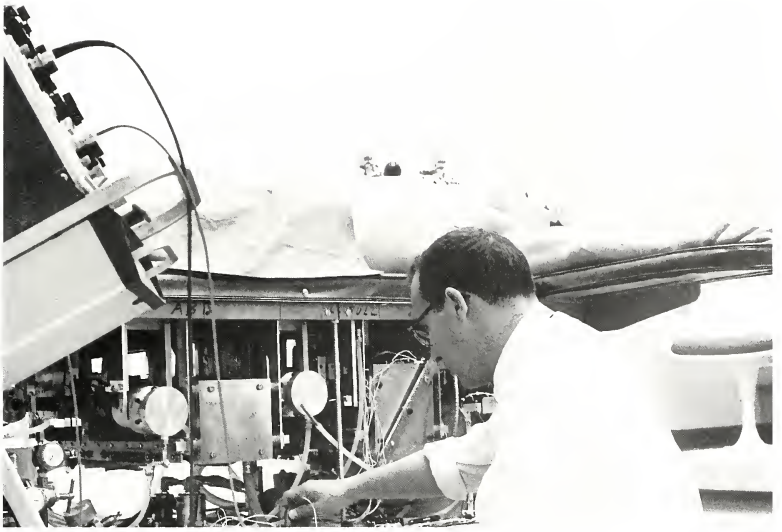
Center for Health Care Research and Development to draw up plans to study the "cost-effectiveness" of Sim One, stating that the original project had merely trained five residents on Sim One. We pointed out that the original project had been a demonstration of the *feasibility* of such a system and was never meant to do more. The outcome, however, was clear: further support for the development of this technology would depend upon a study of "cost-effectiveness."

Until this time, Sim One had occupied some four hundred square feet of space at the Von Karman Center of Aerojet-General. The first step in the new project called for modification of Sim One to permit moving it twenty-five miles to the Los Angeles County–USC Medical Center, where the system would be easily accessible for training purposes. To do this, Sim One had to be "weaned" from the hybrid computer system at Aerojet-General and attached to a Honeywell H316 "minicomputer" (state-of-the-art at the time and the size of a filing cabinet!). The minicomputer and all the other necessary equipment were mounted in a special mobile rack.

In order to expand the capability of Sim One from training only anesthesiology residents to training a broader group of health-care workers, a new right arm was built, designed to permit, among other things, blood pressure measurement, intramuscular injection into the deltoid muscle, extraction of blood through venipuncture, and catheterization of the vein for the purpose of measuring central venous pressure (CVP). A number of other significant changes were reported:

> A new mathematical model was developed to simulate a patient in circulatory failure or "shock". The model allows the instructor to select various degrees of effective volume loss or heart failure, or combinations of both parameters. Equations connect CVP, blood pressure, heart rate and respiration to the state of the internal parameter. The student must then administer fluids appropriately in order to bring Sim One's CVP and palpable pulse contour back to normal.
>
> Programming changes in the anesthesia model allowed two separate respiratory states, apneic and depressed, in addition to the normal state of respiration. In both states, Sim One's ventilation can be assisted by use of a mask and bag or by attachment of a respirator.
>
> In addition, the anatomy of Sim One's oral cavity and trachea were resculptured so that the vocal cords are fully visible when the head is extended for intubation. This last change made Sim One suitable for the teaching of intubation to students other than anesthesiology residents.[5]

Sim One's changes made him much more valuable because it was possible to train many different health-care workers in a variety of tasks. Studies were conducted during 1970 and 1971 to determine whether the use of Sim One reduced costs of instruction. Given the difficulty of



Aerojet-General engineer Taback makes adjustments to Sim One's controlling mechanisms contained within the operating table.

assigning monetary "value" to human life and/or welfare made the final determination of cost-effectiveness almost impossible to achieve. Thus, the studies of cost-effectiveness concentrated on (1) learning gains per unit of time; (2) amount of student time required to reach criterion levels of performance; and (3) the investment of faculty time necessary for student learning—all variables amenable to reasonably precise measurement.

The studies indicated that students who were trained on Sim One performed significantly better than students conventionally trained and that significantly less faculty time was required to bring Sim One–trained students up to criterion levels of performance. In addition, data were gathered on reduction of patient risk but were not reported because of the inherent subjective quality of assigning value to such reduction of risk. Our article in *Läkartidningen* summed it up quite well. "In sum, the University of Southern California School of Medicine has found that its life-like simulator is a practical and effective aid in the training of various health-care professionals. Sim One, when used efficiently, can save enough in faculty hours to justify its cost within a short period of time. Most important, the use of Sim One reduces the amount of risk and

discomfort to which patients are subjected."[6]

Sim One's Last Days

Remarkably enough, Sim One was actually used for training a variety of health-care providers over a period of almost ten years. This feat was truly "remarkable" in that Sim One had been designed and constructed as a demonstration of feasibility, not of utility. The system had not been developed for extensive use, but rather for demonstration and experimentation. Instead, literally hundreds of health-professional students were trained under the guidance of Kaaren I. Hoffman, who also collected and reported effectiveness data.

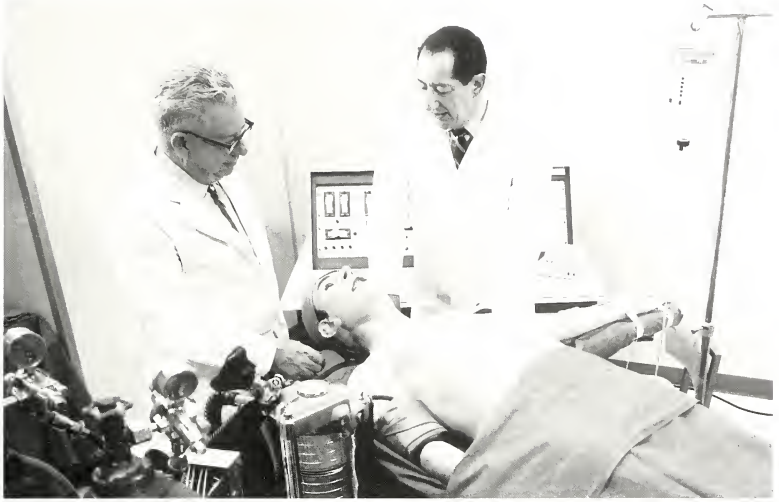
These health-care providers included nurses, inhalation therapists, medical interns, anesthesiology residents, and emergency-room personnel. In all cases, both students and faculty thought that the experience was most useful and contributed to their increased competency with less risk to patients and less time of faculty necessary for student learning.

Over these years, however, the system began to show signs of wear. Having been constructed as a kind of "breadboard" model with much idiosyncratic engineering, Sim One required more and more attention by the engineers who designed and constructed it, most notably Clark and Taback. In addition, the wear and tear on the plastic skin began to make itself known with little cracks and blemishes, which increasingly could not be repaired without leaving noticeable marks. Through all of this period of gradual deterioration, however, training runs continued and Sim One was still providing trainees with learning experiences which held no threat to patients.

During this period of decline, Hoffman and I, with Ronzoni's invaluable support, continued to search for funding to further this innovative effort. But this was 1975 and 1976, and the times were against us. Between some internal administrative problems and a changing national posture with regard to support for education, outside funding for continuation was not found and Sim One's days were numbered.

Those "internal administrative problems" literally killed the future of the simulation effort. Ronzoni had managed to obtain a promise of additional funding from a governmental agency on the condition that the request for funding not exceed a certain amount and that the proposal be submitted by February 1, 1974. The proposal was prepared under the pressure of this deadline and was completed as I left the country for three months to conduct a workshop in Sri Lanka and then to serve as a Visiting Professor in the Department of Surgery at the University of Adelaide. The proposal had to be processed through a USC system in which department chairmen had to "sign off" if one of their faculty members was involved in the project. One such chairman refused to sign off because he, himself, was not "written in" as a "Co-Principal Investigator." By the time the Dean of the School of Medicine had settled this problem in my absence, the deadline had passed and Ronzoni—who had carefully arranged the contract—was informed that the available funds had been used for some other project!

When I returned, efforts were made to bring the two departments together in a common effort to locate other funding. By the time that the internal problems were resolved, however, the funding agencies were no longer interested—particularly in a project which would take place in a setting



"Proud parents," Denson and Abrahamson, enjoy a moment of satisfaction with their "brainchild," Sim One.

in which there had been such contention and conflict.

The actual final demise of Sim One speaks well to the low esteem the academic world really was developing for education. The simulation system was housed in a one-floor barracks-like building just outside the Los Angeles County General Hospital, in fact called "Barracks G." The hospital administration made a decision that Barracks G should be converted to an administration home for the hospital chaplains and ordered Sim One to be moved. At the same time, however, the hospital administration stated that it did not have space to accommodate the system (roughly four hundred square feet) and requested the School of Medicine to provide space—despite the fact that all of those being trained on Sim One (hundreds per year) were either employees of the hospital or others providing care in the hospital. The School of Medicine protested that it, too, had a shortage of space, and an impasse of sorts was reached.

As luck would have it, while these "discussions" were taking place, construction was begun on refurbishing the barracks for the chaplains. One morning, the construction workers broke through a wall from a room adjoining the room housing Sim One; the workers, of course, found this "body" (Sim One) on a table and medical equipment all around—including hypodermic needles. They notified the security office which, in turn, called the hospital pharmacist, instead of Hoffman or me. That hospital pharmacist,

on hearing that there were hypodermic needles "just lying there," ordered the security people to bring the needles to him—and he proceeded to destroy them! Unfortunately for all concerned, the needles were magnetically coded in such a way that the simulation system could sense what was being injected into Sim One. (All injected substances were distilled water. As the magnetically coded needle was inserted into the intravenous portal, a coil in that portal "read" the code and informed the computer as to what was being injected.) These needles were truly a *sine qua non* of the system. Furthermore, the needles had been especially prepared by a West German company which had "gone out of business" in the meantime. The needles, thus, could not be replaced; a new system would have had to be designed—but without funds, of course, to do so.

A sad postscript to this sorry tale is that Sim One still had to be moved and no space was available. While the administrations of both hospital and school were engaged in desultory discussions concerning this problem, the system was in fact moved to a School-of-Medicine classroom which was being used for storage purposes. When the manikin on its table arrived, it was discovered that it could not fit through the door without removing the door from its hinges. Instead of doing so—or locating another space—the "solution" was to "amputate" Sim One's left arm along with the part of the table holding that appendage!

Thus passed one of the most remarkable innovative teaching aids in all of medical education. All that remains is a set of still photographs, two motion pictures (one silent and a shorter one with sound), and a number of journal articles describing the simulator and its "contributions" to medical education.

The Future

And what of the future? Interestingly enough, at least two similar simulators have been reported in the press—in neither case was there mention of the pioneer work on Sim One. It was as if all such simulation efforts had begun with these new devices.

Today's technology is far superior to that of 1967, when Sim One first appeared, or that of 1971, when Sim One was modified and moved to its "new" home at the Los Angeles County General Hospital. Today, the computer needed to govern all the action could easily be housed in the manikin—or even in the manikin's head, like a real "brain." The necessary animation could be better than ever, thanks to advances in animatronics. The appearance of the manikin could be that much more lifelike, even including areas that Sim One's inventors were unable to achieve: changes in skin color in response to lack of oxygen, "sweating," and-or "crying"; installation of the central-venous pressure capability.

But none of this will take place until funding sources are located. Medical education in general is suffering from a striking lack of financial support. (Indeed, all of education seems to be in this position!) It seems tragic that such a promising technology is now limited to scattered individual efforts by a few dedicated educators and does not realize the broader significance that it deserves. As long ago as 1980, Peggy Wallace and I listed a number of advantages to the use of Sim One, advantages which apply to any such simulations. These included (1) "significant reduction in potential discom-

fort or harm to patients"; (2) capability for "students to learn from mistakes far more readily"; (3) "gradual increase in difficulty of situations faced by the learner"; (4) providing "real time as a factor, requiring students to perform with real urgency"; (5) "introduction of emergencies at the push of a button"; (6) "training in the management of chronic conditions"; (7) "variation in the manikin's response so that the student does not become conditioned to a one-response format or pattern"; (8) saving of "faculty time and/or student time"; and (9) standardization of "complex tasks . . . for effective, objective assessment of student skill level."[7]

Perhaps that day will come, the day envisioned by Ronzoni and me, when every medical school and every teaching hospital will have a set of patient simulators to be used for teaching and testing those who provide health-care services. Perhaps the emergence of "managed health care" will stimulate the development and application of this technology as a significant effort to improve training, to provide a valid certification mechanism, and thus to reduce potential discomfort and harm for patients who presently run those risks while providing for the learning by novice health providers and health-professions students.

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Notes

1. Stephen Abrahamson, "Human Simulation for Training in Anesthesiology," in *Medical Engineering*, ed. Charles Dean Ray (Chicago: Year Book Medical Publishers, Inc., 1974), 370–74.

2. For detailed engineering information, see ibid.

3. Stephen Abrahamson, Judson S. Denson, and Richard Wolf, "Effectiveness of a Simulator in Training Anesthesiology Residents," *Journal of Medical Education* 44, no. 6 (June 1969): 515–19.

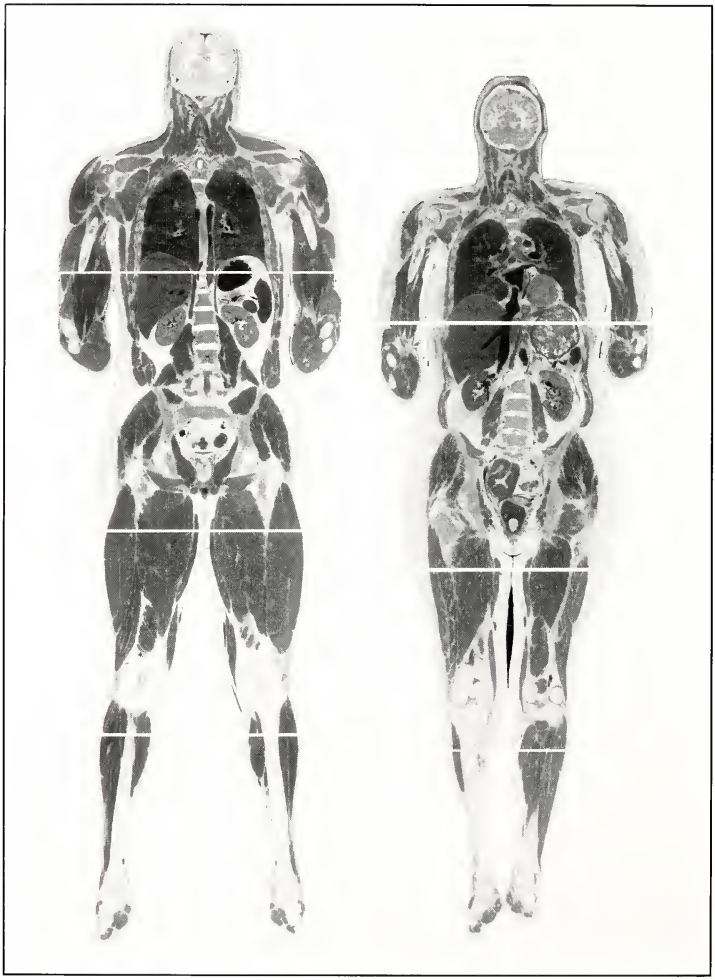
4. Judson S. Denson and Stephen Abrahamson, "A Computer-Controlled Patient Simulator," *JAMA* 208, no. 3 (Apr. 21, 1969): 504–8.

5. Stephen Abrahamson and Kaaren I. Hoffman, "Sim One: A Computer-Controlled Patient Simulator," *Läkartidningen* 71, no. 47 (Nov. 20, 1974): 4756–58.

6. Ibid.

7. Stephen Abrahamson and Peggy Wallace, "Using Computer-Controlled Interactive Manikins in Medical Education," *Medical Teacher* 2, no. 1 (1980): 25–31.

STEPHEN ABRAHAMSON is Professor Emeritus of Medical Education at the University of Southern California School of Medicine. In 1963, he founded the Department of Medical Education and served as its Chairman until 1991. He has been Chairman of the Group on Educational Affairs of the Association of American Medical Colleges (AAMC) and President of the Society of Directors of Research in Medical Education. At the National Board of Medical Examiners (NBME) he was Member-at-Large, Chairman of the Research Advisory Committee, and Chairman of the Liaison Advisory Committee. He has been an invited educational consultant to more than half of the North American medical schools as well as to medical schools in Europe, Africa, Asia, Australia, and New Zealand. Recognition of his innovative scholarship has included a Senior Fulbright Award, the John Hubbard Award from the NBME, the Merrill Flair Award from the AAMC, and an honorary doctorate from the Medical College of Ohio. His most recent book is *Essays on Medical Education* (1996).



Virtual coronal plane computer reconstructions from the original, transverse cross sections of the Visible Human Project. These images were made by stacking the images (1,878 for the male and 5,189 for the female) and then slicing the resultant stacks from head to foot at the illustrated depth.

The Visible Human: A New Language for Communication in Health Care Education

Victor M. Spitzer

All health care professionals have a common underlying problem in managing the care of their clients—to understand the geometrical relationship, structure, and function of the components of a system (the patient) at precise points in time (the visit) without disturbing the system.

A New Model of Anatomy

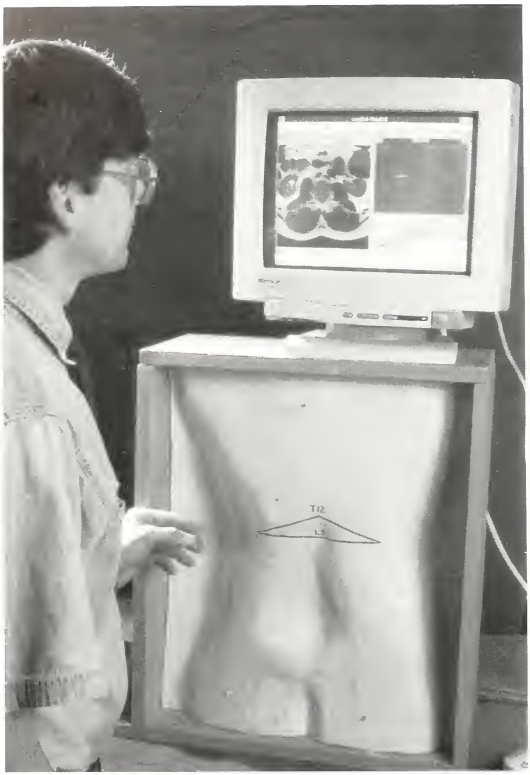
Health care educators have met the challenge not only by expanding the professional's knowledge about the generic human body (anatomy) but also by improving methods of gaining anecdotal information about the specific body, including physical examination and diagnostic imaging.

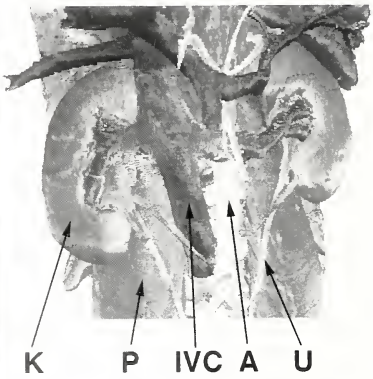
The development of the model of generic human anatomy takes various forms for different health care professionals. Cadavers have been an important part of that training, and variation in anatomy is taught by experience with different cadavers. The cadaver provides a powerful interactive learning experience for the student, but it must not be overlooked that the cadaver is only an approximation to the structure and function of the live patient. The majority of health care professionals do not have firsthand cadaver experience and derive their perception of the human body from textbooks and classical didactic material.

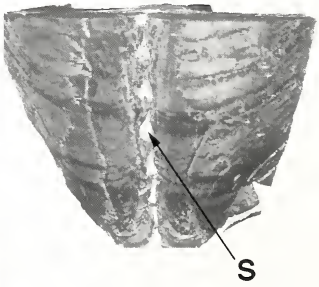
The Visible Human affords us the opportunity to enhance communication of anatomical knowledge to all students and to facilitate and promote communication between health care professionals (and people in general) with diverse backgrounds, levels of training, and complexities of vocabulary. It provides a resource for visual communication that has the potential to better approximate the live human than does the cadaver.

The Visible Human Project

The Visible Human Project was conceived by the National Library of Medicine in 1986 to create a volume database of male and female human anatomy that could be computer accessed, controlled, and distributed. The technology was developed at the University of Colorado School of Medicine; the principal investigators were David G. Whitlock and the author. Our intent was to image whole male and female cadavers at thinly spaced intervals. The Visible Human Male was completed in October 1994. The Visible Human Female was completed in October 1995. Together, they comprise the Visible Human Dataset,







Karl Reinig, inventor of the celiac plexus block simulator (an abdominal anesthesia procedure), demonstrates the procedure at the Center for Human Simulation. Holding the needle in his left hand, he views the posterior abdomen and back on the monitor. The plastic shell below (which is molded to the exact shape of the Visible Human back) provides authentic haptic sensation. The upper-right image is a three-dimensional visualization, from an anterior view, of the structures in the posterior abdomen; the anterior surface of the aorta is the target. Behind the plastic back are three motors and an articulated arm (from Sensable Technologies) that are coupled to the Visible Human data and provide forces indicative of the needle resistance (letters indicate, respectively, kidney, psoas muscle, inferior vena cava, aorta, and ureter). The lower-right image is a posterior view of the posterior muscle and ligament layer deep to the skin and subcutaneous fat. The student can feel any of the tissues, either on the correct path to the target celiac plexus or on a path that is completely off target. Ligaments conceal the spinal processes (S) of the vertebrae.

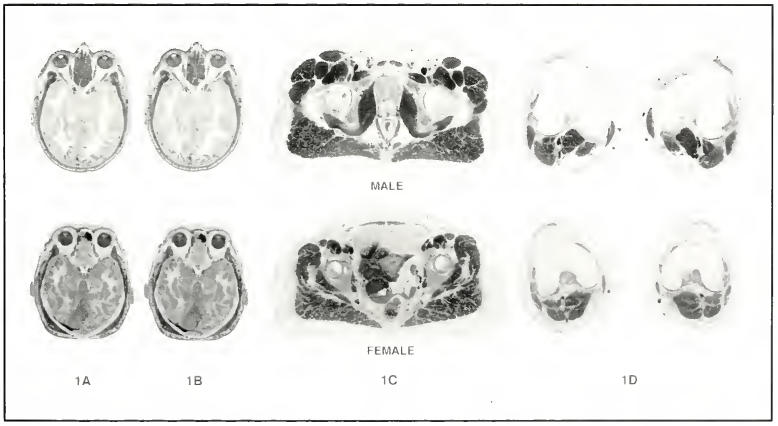
a trademarked collection of more than thirteen thousand images. The dataset includes radiographs, computed tomography images, and magnetic resonance images of the intact cadavers as well as 1,878 male and 5,189 female photographic images of thinly sliced cross sections of the bodies.

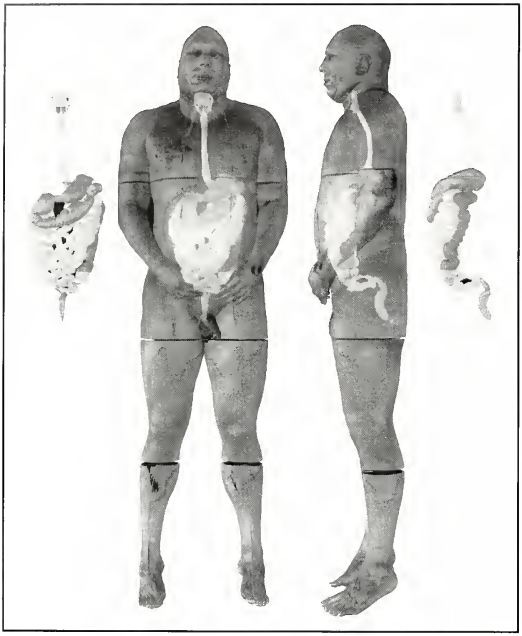
All images of the Visible Human Dataset are related. Each cadaver can be reassembled and recut in the computer to visualize the intact cadaver from any desired cross section. The Visible Human therefore combines the reality of the original images (transverse to the long axis of the body) with the students' manipulation of the three-dimensional stack of original images to produce virtual reality images at any angle to the long axis of the body.

Virtual Reality Learning Through Assembly

The Visible Human can be disassembled (a process called segmentation) by tissue characteristics as well as by slices. Anatomical structures with unique colors or combinations of unique colors (textures) can be isolated and distinguished from the rest of the body in order to appreciate their size, position, and relative location. After tissue-character-based segmentation, an anatomist identifies or segments anatomical structures of a single-tissue characteristic, based on function or classical anatomical subdivisions. Then the user can visualize three-dimensional anatomical structures of the body regardless of color; individual muscles of the same color, for example, can be isolated from one another.

Transverse cross sections from the Visible Human Male (upper) and Visible Human Female (lower). The images are photographs of the original cross sections: 1A is a slice through the center of the orbit; 1B is the succeeding slice (for the male, 1 mm from slice 1A; for the female, 0.33 mm from slice 1A); 1C is a cut through the pelvis; and 1D is a cut through the knees.





Three-dimensional rendering of the gastrointestinal system. Organ reconstruction of the esophagus, stomach, small intestine, colon, and rectum was a two-step process of combining views of the isolated and "in situ" systems from both the anterior-posterior and lateral views. First, an anatomist individually segmented and classified the organs by positional analysis; then, each was reconstructed in relation to the whole body.

With refinements at strategic points, the Visible Human will facilitate interaction with the body and all of its tissues with haptic (feeling), aural, and olfactory feedback in addition to the classical visual feedback. Our goal is to provide health care students with the same quality of simulation used for decades in the aircraft industry.

New Directions for Human Simulation

Human simulation encompasses the fields of anatomy, physiology, pathology, pathophysiology, evolution, and development. Health care education is now in the infancy stages of developing engineering models to document the enormous panorama of human life.

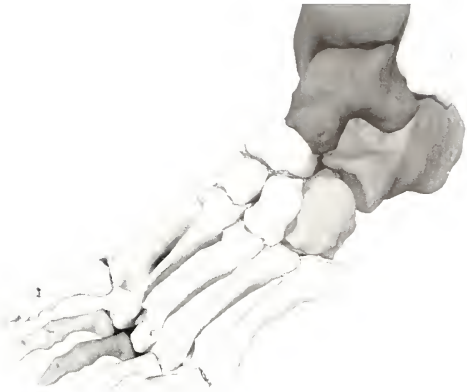
The Visible Human Project provides the foundation for modeling a single vision of the anatomy of a single human at a single point in time. The great challenge for simulations is the addition of physiological models to transform those cadaveric visualizations into lifelike models with functioning systems. Further refinement of the physiological models will allow the visualization of development, thereby permitting the transforming of one lifelike form into the same form at any time in its normal life.

In an ideal extreme, the Visible Human would model from embryonic to geriatric stages—from life to death. With further expansion of our knowledge base and abilities, we will model both abnormal development (pathology and pathophysiology) and abnormal events (trauma).

When we have achieved nirvana in the world of simulation, we will be able to extrapolate or predict different people from a single specimen and to control time in the model with a precision that illustrates evolution of the species. At such a point in time, the effort will most probably have exceeded or incorporated the combined efforts of the Human Genome Project and the resources underpinning our exploration of space, but the foundation for those developments has begun with the Visible Human.

Today, we are finalizing the expansion and conversion of our laboratory at the University of Colorado School of Medicine

Three-dimensional rendering of the lower abdomen and quadriceps of the right thigh, illustrating the precise texture of those muscles in the Visible Human Male. The view was produced by reflecting simulated light rays from the "muscle colored" set of data, which illustrates muscles as a tissue category but does not distinguish individual muscles from each other.



Three-dimensional rendering of the skeletal foot. This rendering is possible only because each bone has been individually segmented and classified by an anatomist, not just by such image characteristics as bone density from either computed tomography or color from the photographic data. If only image-based tissue characteristics were used in the database, all bones would be the same shade of gray and thus indistinguishable at many joints.

to the Center for Human Simulation. The general purpose of the Center for Human Simulation is to facilitate the collaboration of anatomists, radiologists, computer scientists, bioengineers, physicians, and educators to promote the application of the Visible Human and other anatomical data to basic and clinical research, clinical practice, and teaching. The primary goal of the Center for Human Simulation is to develop interactions with computerized anatomy in virtual space. Among our achievements with the Visible Human and other data have been surgical cutting, needle insertion, dental probing, and ophthalmological procedures (all with haptic feedback).

As the Visible Human image database is developed as a model of human anatomy and extended as a visualization of human physiology, we will begin to realize its potential to teach variations in normal human anatomy. Most important, as a single electronic representation of the body—with all its variations and forms—the Visible Human will facilitate cross-disciplinary understanding and cooperation through more efficient communication. Unlike a single cadaver (which is experienced by few) or a textbook or software (which is normally targeted at a focused audience), the Visible Human Dataset and its derivative forms can be used in visual communication throughout the health care industry and beyond.

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VICTOR M. SPITZER is Associate Professor in the Departments of Cellular and Structural Biology and Radiology at the University of Colorado School of Medicine, Denver. His formal training was in mathematics, physics, chemistry, and nuclear engineering. His professional experience is in radiological imaging and anatomy. The raw data for this work is from the Visible Human Project, for which he was Co-Principal Investigator with David Whitlock from 1991 to 1995. Extension of this work to other specimens and the utilization of this and future data is the goal of the Center for Human Simulation at the University of Colorado, which he directs. The Visible Human Project was recognized by the 1996 Satava Award at the Medicine Meets Virtual Reality Conference for "transformation of medicine through communication" and by the Bonfils-Stanton Foundation Award in recognition of "unique contributions in the field of science, including medicine." Utilization of the Visible Human Project by health care professionals, other disciplines, and the general public for communication of anatomical knowledge—from primary schools to adult education—is his passion.

Additional Information on the Visible Human

For a summary of the Visible Human Project, including every male photographic anatomy image from the dataset, see Victor M. Spitzer and David G. Whitlock, *Atlas of the Visible Human Male: Reverse Engineering of the Human Body* (Sudbury, Mass.: Jones and Bartlett Publishers, 1997), available from the publisher's website, http://www.jbpub.com.

Additional background on the history and implementation of the project can be found in Victor M. Spitzer, Michael J. Ackerman, Ann L. Scherzinger, and David G. Whitlock, "The Visible Human Male: A Technical Report," *Journal of the American Medical Informatics Association* 3, no. 2 (1996): 118–30.

Both male and female images of the dataset are available on the internet. The transverse images are free, with a license, from the National Library of Medicine. For details on both the original data and major products using the data, see the Center for Human Simulation website at http://www.uchsc.edu/sm/chs.

The Visible Human Male data (in 24-bit form), as well as the classification masks, can be purchased from the Gold Standard Multimedia website at http://www.gsm.com.

JPEG compressed data can be obtained from the Research Systems, Inc., website at http://www.rsinc.com.

Medicine Beyond the Year 2000

Richard M. Satava and Shaun B. Jones

Thanks to a rapid infusion of information technologies (ITs), miniature optics, sensors, noninvasive diagnostics, and robotics, modern medicine—most notably surgery—is undergoing an upheaval whose dimensions are not fully appreciated even by its practitioners.

A leading driver of such technical advances is laparoscopic surgery, a "minimally invasive" surgery in which slender probes mounting tiny cameras and long hand-controlled surgical tools are inserted into the body through a tiny incision. With laparoscopic procedures, the surgeon operates without directly seeing or touching the tissue, unlike traditional open surgery. Although laparoscopic surgery was first used in 1986 for gallbladder surgery, it is rapidly evolving to meet many needs in modern medicine. By adding high-resolution noninvasive imaging taken before or during the operation, for example, a laparascopic surgeon can see more detail and visually access more difficult surgical problems than is possible in traditional open surgery.

Today, laparascopic surgery also exploits another advance: virtual reality (VR). VR puts the viewer—a surgeon, physicist, engineer, data manager, or student—into a computer-generated synthetic environment with realistic, moving three-dimensional (3-D) images. VR not only supports all phases of surgery but can be used to predict potential outcomes. A surgeon can plan an operation, explore alternatives, and rehearse procedures virtually before performing them. An orthopedic surgeon can predict future wear patterns in a repaired joint. A cosmetic surgeon can predict aging in a facial skin patch.

By drawing on VR, generic image data, and patient-specific data (including preoperative and intraoperative computer-assisted scans), a surgeon can create an accurate 3-D representation of a patient's target area. Thus, by using tiny actuators and other tactile devices, the surgeon can "operate" on the VR image of a damaged organ; VR will even provide the "feel" of the organ as if in traditional open surgery.

Virtual Reality in the Classroom and Clinic

VR and improved tactile devices open up another market: surgical simulators for training and accreditation. Simulators permit a broad array of surgical experience; they boost productivity and reduce instructional costs by letting students practice on simulated "virtual humans" instead of scarce, costly cadavers or animals. Computer-hosted simulators with multi-

The opinions or assertions contained herein are the private views of the authors and are not to be construed as official or as reflecting the views of the Department of the Army, the Department of the Navy, the Advanced Research Projects Agency, or the Department of Defense.

media curricula not only could replace live classroom instruction but could be distributed over telemedicine networks for distance learning and continuing medical education.

Future payoffs of surgical VR include telemedicine and virtual teams. High-bandwidth data links and high-fidelity optical and tactile sensors will let geographically separated surgeons form virtual teams for telesurgery on distant patients. VR-aided telesurgery, which is being pursued by U.S. military services, may revolutionize battlefield medicine and medical care in civilian disasters.

In short, VR-aided surgery has a bright future. After lagging behind such professions as engineering in using ITs and computers, surgery promises to become a technological pacesetter, thanks to growing synergy with a commercial IT market where new products can emerge in months rather than years. Moreover, emerging capitation-based markets increasingly will reward advances in lower-cost, minimally invasive outpatient surgery over traditional open surgery.

The VR Interface and the Coming Surgical Revolution

The video monitor is the focal point for modern laparascopic surgery, advances in VR, digital imaging, 3-D scientific visualization, networking, and electronic databases. The monitor is the surgeon's primary interface with both the real patient and the patient's digital representation, which is generated from pre- and intra-operative data and imagery streams that may be imported during surgery. Other interface options include holograms, palmtop computers, or—especially for VR—helmet- or head-mounted displays (HMDs) that position a mini-display in front of each eye.

The DataGlove and a head-mounted display developed by Telepresence Research

In essence, the surgeon's monitor and other sensory interfaces are becoming the single most critical tool in surgery. A major advance in interface technology will be voice control for "hands-off" control in complex procedures. A first-generation voice control system is used in a robotic endoscopic camera holder, which can be trained on a specific voice.

Minimally invasive surgery has exploited VR techniques that were pioneered by the National Aeronautics and Space Administration for training astronauts in complex remote-control activities. The HMD is frequently used with the Dataglove with fiber-optic sensors. Thus, pointing in a direction, the operator can move around in the world, "fly" through simulated objects, and pick up or move simulated objects.

Five factors contribute to the realism of virtual surgery simulators:

1. fidelity, which requires high-resolution graphics;
2. variation in organ properties, including deformation from morphing and kinematics of joints;
3. simultaneous organ reactions, including bleeding from an artery and bile leakage from the gallbladder;
4. interactivity of surgical instruments and organs; and
5. sensory feedback, both tactile and force.[1]

The two broad categories of VR are *exocentric* ("through the window") VR, in which a person looks into the virtual world from an outside vantage point, and *immersive* or *egocentric* VR, in which a person feels completely immersed in a virtual world. For surgeons, an immersive environment might be the interior of an artery, a body cavity, or a specific organ. Interfaces for immersive VR environments may offer aural and tactile interfaces, including, for example, sound pitch to convey proximity.

Immersive environments that are described as *synthetic* (vs. "virtual" environments) are being developed for high-end uses, including medicine, by companies like MuSE, Inc., of Albuquerque, New Mexico. That company has drawn on technologies from the Department of Energy (DoE) to develop a "multi-user synthetic environment" (MuSE) tool. By displaying those images on high-performance video monitors or other display interfaces, today's "digital physician" has access to a full digital representation of the patient. He or she has available, during surgery if necessary, a full set of patient data, including diagnostic imagery, video, and textual data.

With such data richness, a VR interface gives the surgeon unprecedented power in data access and manipulation. The surgeon can import computerized scans of the patient, including scans conducted during surgery, and fuse them with real-time video images for "X-ray vision." Before doing a procedure, the surgeon can use the workstation or HMD to practice on a virtual patient and then flip a switch and use the same interface to work on a real patient.

Maximizing Image Computing Power and Touch Sensations. Due to limited computer power, surgical VR simulators have needed to trade off desired features—sacrificing, for example, graphical realism for high-fidelity interactivity. In their study of media displays, J. Coleman, C. C. Nduka, and A. Darzi have shown that VR displays offer between two to fifteen frames per second, depending on image complexity.[2] By comparison, video cameras and televisions can run twenty-four to thirty frames per second. The low-frame speeds derive from the computationally intensive computer generation of VR objects. Typically, 3-D virtual objects are made up of two-dimensional polygons. Realistic computer-generated reconstruction of the abdomen, for example, requires five hundred thousand polygons per second for realistic images. Higher rates are needed for magnetic resonance imaging (MRI) or computer tomography (CT) images.

Coleman and colleagues also identify improvements in high-fidelity tactile or *haptic* sensors and actuators that give VR organs and tissues the feel of the actual counterparts, including responses to a surgeon's probing, tugging, cutting, and suturing actions. Those devices represent one of the toughest challenges in surgical VR, as they must convey to the surgeon the shape, position, texture, temperature,

force, and firmness of organs and tissue with high spatial accuracy. The TeleTact Glove, developed by the Advanced Robotics Research Centre of Salford, United Kingdom, simulates pressure on fingers and palm by inflating tiny computer-controlled air bladders. Other devices place small vibrating transducers on the skin to generate discrete sensations and surface textures; they do not replicate pressure, however. Full tactile/haptic fidelity may require an operator-worn exoskeleton, which adds to cost and complexity.

Commercial and Governmental Programs that Drive Surgical VR

The VR revolution in medicine is being speeded by several simultaneous advances in various technical sectors, all moving quickly from lab to market. Many of those developments, although nonmedical, have significant implications for medicine. Commercial drivers include rapid growth in high-bandwidth data and Internet links. Cable companies in some cities offer cable modems with ten megabyte per second data rates—considerably faster than current intercity "T1" (1.5 megabytes per second) high-speed links. Some arcades make use of such cables by participating in VR combat games between geographically separated teams.

Modern flight simulators are so realistic that simulator-induced nausea is a recognized hazard. The "distributed simulators" of the U.S. military services allow members of a special-forces squad to practice their mission, use the latest imagery of an enemy target or other objective, then climb into their helicopters for the real mission.

Remotely controlled experiments and distributed virtual teams are crucial elements of undergoing federal research. The DoE-sponsored Distributed Collaboratory Experiments Environment (DEEE) project combines high-capacity data links with an immersive-VR roomlike environment (known as CAVE) whose development was funded by the DoD and the National Science Foundation (NSF). The DEEE will allow multiple labs to team on complex experiments at remote sites. VR data links for such experimental environments have been used over transatlantic distances.[3] Similar techniques for virtual prototyping and agile manufacturing are also being explored. Multisite, interagency collaboration reportedly is a major element of those programs.[4]

User interfaces represent another area of advance. Flat-panel HMDs and traditional monitors are improving, with new designs offering extremely high resolution that approaches photographic quality. Developmental computerized voice-recognition systems can respond to words in various languages or dialects.

Instructional Simulators and Telesurgery

VR may offer the greatest benefits in medical education and training, with telesurgery another important beneficiary. The U.S. government is funding work in both areas.

Surgical Training Simulators. The training of thousands of surgeons around the world in minimally invasive surgery has traditionally depended on the use of pigs. That method is not only expensive but relies on a limited number of experienced teachers. According to Mark D. Noar, the learning curve for such procedures as laparoscopic cholecystectomy typically requires fifty trials.[5] Until that point is reached, according to Noar, the minimally invasive practitioner may have a sharply increased

complication rate.[6]

Laparoscopic surgical simulators can reduce those risks. David Ota and others have noted that since competence assessment involves rule-based judgment, incorporating so-called fuzzy logic in VR-based teaching simulators allows measurement of student progress.[7]

VR supports both didactic and experiential teaching. In the first mode, it can provide 3-D visualization of basic anatomy and physiological principles. It then can switch to an experiential or exploratory mode to reinforce what the student has learned. By "seeing" shock realistically or by traveling through the lymphatic or circulatory system, a student grasps more than he or she could from reading books, watching blackboards, or dissecting cadavers.

Moreover, such instruction can combine 3-D imagery with a fourth dimension: time. A multimedia VR system developed by Helene M. Hoffman of the University of California at San Diego enables students to "fly" into the stomach and grab an ulcer for biopsy.[8] That action can trigger retrieval of the ulcer's histologic micrograph or a videotape of preferred techniques for ulcer removal.

Another critical role for simulators is in evaluating a surgeon's performance. Embedding performance measures in the simulation software allows for competence assessment. Algorithms developed to coach students in real time can also be used to collect historical data on how a practitioner's skills are holding up. The American College of Surgeons is evaluating the potential of simulation-based training for surgical resident education and continuing medical education credits.[9]

Simulators for instruction in laparoscopic surgery have been on the market since 1993. Two VR simulators developed by Kevin Woods[10] and David Hon[11] comprise a simple mannequin into which the handles of laparoscopic instruments are mounted, providing force feedback. A virtual abdomen with liver and gallbladder is represented on the video monitor.

A Laparoscopic Surgical Skills Simulator (LSSS), developed by Ixion from Noar's work at St. Joseph and Franklin Square Hospitals in Baltimore, is described as a "completely interactive simulator that uses open-ended learning with staged skills pedagogy."[12] It includes a touch-screen monitor and a molded torso with skin that duplicates the feel of instrument penetration. LSSS exposes students to three patients with eleven different problems. Its physics-based graphic modeling system uses polygons to model organs and then welds together high-resolution background images through special "video plane programming" and image projection. LSSS also employs a unique proprietary "nonmechanical variable tactile resistance device" to simulate both the feel of tissue resistance to cutting or probing.

A different path undertaken by one of the authors in collaboration with VPL, Inc., of Redwood City, California, employed the DataGlove, an HMD, a virtual scalpel, clamps, and a VR representation of an abdomen.[13] Students can virtually fly through the abdomen to learn basic physiology.

A laparoscopic cholecystectomy simulator aimed at clinics is the Virtual Clinic from the Ciné-Med Corporation of Woodbury, Connecticut. The Virtual Clinic simulates a fully textured liver, gallbladder, related structures, and four laparoscopic instruments. The tactile feedback of the Virtual Clinic has been described as "amazingly realistic."[14] Future

versions will include such landscapes as the abdomen, thorax, pelvis, and heart, complete with CT and MRI imagery.

Making VR Equipment Unobtrusive

Creating user-friendly equipment has been a major challenge for designers of surgical VR simulators. Doctors, after all, wish to focus their attention on the patient and not on the HMDs, datagloves, body-tracking suits, or exoskeletons.

One tack taken by Germany's National Research Center for Computer Science is a simplified "Responsive Workbench" tabletop VR environment.[15] Developed with input from physicians, the Responsive Workbench projects a virtual human with semitransparent skin for surgical planning. Wearing a dataglove, the user can manipulate the body in any way—even extract a bone for examination! One workbench variant simulates ultrasonographic examination of a beating heart. The user can rotate the model to view the heart from different angles and also view it from inside.

User-friendly design can exploit the fact that most of today's medical students are highly computer-literate from years of playing interactive computer games. Moreover, commercial and military developers of VR can exploit current trends in miniaturization and embedded intelligence for interfaces, displays, voice control, and body- or motion-tracking sensors.

For example, one display method that goes beyond current HMDs and other flat-panel displays is the *virtual retinal display* (VRD) under development by the Human Interface Laboratory of the University of Washington at Seattle.[16] Funded by the Defense Advanced Research Projects Agency (DARPA), that work focuses on projecting individual image pixels directly into a viewer's retina, which creates the illusion of a translucent computer screen. The VRD mounts on an eyeglass frame or some other platform.

Virtual anatomy of the abdomen with instruments supplied by the "Virtual Clinic" of Ciné-Med Corporation

A "virtual cadaver" as displayed and used by students for an anatomy lesson at Fraunhofer Institute, Stüttgart, Germany

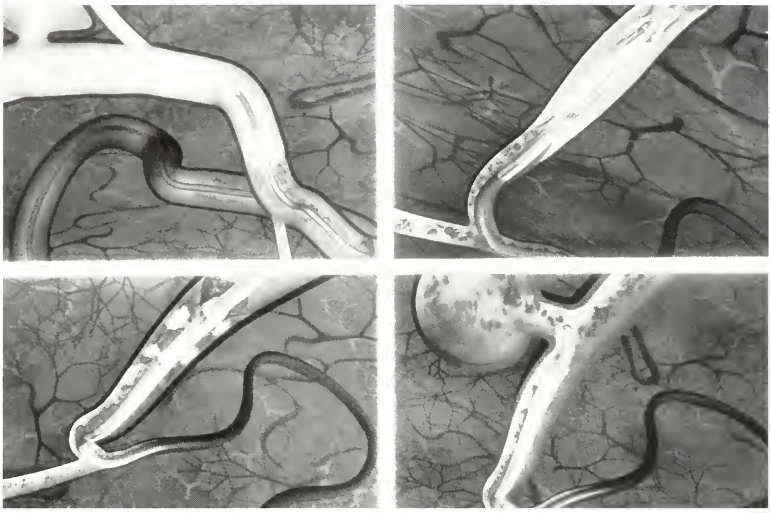
Research on improved display techniques for medical databases is also underway at the Human-Computer Interaction Laboratory University of Maryland, College Park. The center is developing methods to quickly retrieve images from the Visible Human Dataset of the National Library of Medicine.[17]

Software Engineering for the Digital Physician

State-of-the-art software currently endows physically-based organ models with morphing and elasticity properties. Prototype software is being tested in medical teaching hospitals for outcomes research.

A leader in the field of medical software engineering is HT Medical, Inc. (formerly High Techsplanations) of Rockville, Maryland, which calls itself "the world's only company focused exclusively on VR medical simulation software." The company creates VR software for simulation of interventional radiology (catheterization, stent deployment, and angioplasty), vascular access (intravenous insertion and blood drawing), battlefield injury treatment, specialized instruction in cardiology and gastroenterology, and general instruction in endoscopy, urology, neurology, and gastroenterology.[18]

At a March 1996 demonstration of an HT Medical, Inc., VR simulator, radiologists manipulated catheters, guidewires, and sheaths (through which interventional radiology instruments could be passed). The simulator tracked all three devices as well as the feel of each as it encountered



An HT Medical, Inc., virtual reality simulation for training in vascular surgery procedures

various conditions inside blood vessels. A radiologist could virtually inject dyes for angiogram of blood vessels, treat a blockage with angioplasty, or administer clot-busting drugs by catheter. The simulator is programmed to respond to errors with appropriate "complications," including balloon ruptures, punctured blood vessels, and atherosclerotic plaque in older patients. A second-generation HT Medical, Inc., angioplasty simulator featured a computer with enough power to display fifteen frames per second of adequately detailed vasculature for extremely accurate physiological modeling.

Virtual Humans as VR Data

Realistic data for surgical simulators can be taken from patient-specific images or from databases. Patient-specific CT and MRI data can be acquired before the operation or, in an emerging trend, even during the operation itself. Magnetic resonance fluorescence imaging, which offers image refresh rates as low as .5 seconds, is being used for real-time guidance of microsurgical instruments. Douglas A. Ortendahl and Leon Kaufman report that such feedback is extremely useful in abdominal procedures, where organs are in motion due to respiration.[19] While not perfect, it represents the first steps toward the realization of real-time MRI image-guided surgery.

N. D. Thalmann and D. Thalmann have described the usefulness of virtual humans in plastic surgery, where analysis of facial expressions and musculature is critical, and in orthopedics, where prosthesis design, the interaction of artificial joints with walking or other motion, and outcomes analysis (including outcomes

analysis during the surgery itself) are crucial.[20] The premier source of photo-tomographic data is the Visible Human Project, described elsewhere in this issue.[21]

Remote Surgery, TeleSurgery, and Telementoring

While laparoscopic surgery couples the surgeon's hand directly to the instruments at the end of the probe, telesurgery replicates the process in a "distance" mode. It uses sensors to detect hand motion, converts that motion to electronic signals, transmits the signals to a remote operating site, and converts them into laparoscopic tool responses.

Among current examples of telesurgical systems and research programs are the Green Telepresence Surgery System, the DoD telesurgical methods for battlefield casualty care, the Massachusetts Institute of Technology (MIT) system for eye telesurgery, and telementoring programs for distance monitoring of surgical procedures.

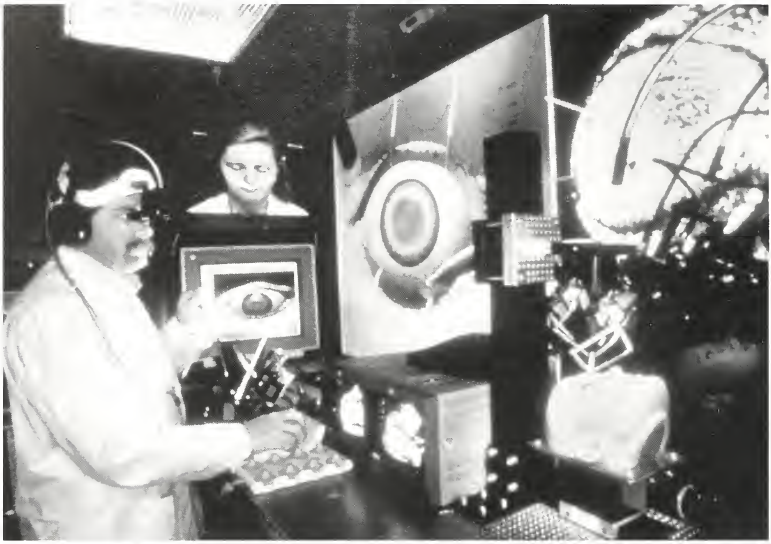
The Green Telepresence Surgery System. The Green Telepresence Surgery System is a remotely-controlled system that addresses three problems in laparoscopic surgery: lack of sensory feedback, poor dexterity, and absence of 3-D vision. The Green System features a remote operative site equipped with a stereoscopic camera and a dexterous manipulator. A surgical workstation adjacent to the operative site is equipped with a 3-D monitor and instrument handle controllers whose feedback and dexterity resemble those of open-surgery instruments. The patient may be nearby or at a remote site (e.g., a battlefield or space station).[22]

By importing and overlaying diagnostic imagery on the video image, the Green system enables a surgeon to operate in open-surgery mode. Image fusion is also useful for endoscopic or microscopic surgical procedures. The Green System workstation can import VR simulations as well. The current one-handed Green System offers five-degrees-of-freedom dexterity and uses paired cameras for stereo vision. The next generation will have two six-degrees-of-freedom surgical hands and will replace the cameras with a stereoscopic laparoscope.

Battlefield Casualty Care. The most aggressive development of telesurgery is in the area of battlefield casualty care, funded by the DoD. VR simulation under that program emphasizes ballistic wounds, bone fragmentation, and other aspects of wounds from high-speed metal objects. Simulations now run at twelve to fifteen frames per second, with a goal of thirty frames per second. Unique elements include robotic operation on patients inside an armored medical vehicle situated near the front lines, fast-paced operations in which remote telesurgeons tackle only the most critical problems (leaving lesser problems and patient preparation and aftercare to forward medics), and simulators tailored for combat medics.

A combat medic might train on a simulator using an HMD while sitting on a machine resembling an exercise bike that moves him across his simulated terrain. When he "sees" a soldier fall, he moves over to tend him. Kneeling over him, his HMD shows a high-fidelity image of the battle wounds for which he is training. The medic stabilizes the soldier, places him in a special transport pod, and moves on to his next casualty.

Eye Telesurgery at MIT. An experimental ophthalmology surgery system pioneered at MIT is based on high-fidelity master/slave interactions. Through such



The eye telesurgery system, including virtual reality trainer, perfected at the Massachusetts Institute of Technology

advanced telesurgery, MIT surgeons perform retinal procedures with 10-micron accuracies on moving eyes. The unit converts hand motion to electronic signals for computer-aided teleoperation. A computer tracks patient eye motion of two hundred cycles per second and adjusts the surgical instrument's motion to the eye motion. Filters remove any tremors from the surgeon's hand. A major element of the work is "microsurgical robots," which operate in a master/slave relationship to the surgeon. One eye surgery simulator employs an "active mannequin" whose eyes have tissuelike elastic polymers for realistic feel and fast-response artificial muscles for movement.[23]

A computer reduces master/slave motion by 100:1 and impedes unsafe movements (an overly rapid movement, for example). Blood lines and other features can be modeled from different viewing perspectives—as one-dimensional lines, for example, when viewed from outside but as 3-D tubes when viewed from inside the eye.[24]

Telementoring. Telementoring represents another payoff of high-bandwidth communication links. Tests by a Brady Urological Institute team at the Johns Hopkins Medical Institutions in 1995 produced a 95.6 percent success rate (twenty-two of twenty-three cases), with an experienced surgeon monitoring an inexperienced surgeon more than one thousand feet away. The experiment featured real-time video, two-way audio links, a robotic arm to control the videoendoscope, and a telestrator.[25]

An even more impressive test was

conducted in 1996, using satellites and landline, between The Netherlands and Hawaii. One problem was a modest time delay that, while acceptable for telementoring, could become a more serious issue if robotic instrument manipulation was involved.[26]

Other Surgical Uses of Virtual Reality and Related Technologies

Robot-assisted surgery, telesurgery, noninvasive diagnostics, training simulators, and rehabilitation aids suggests the variety of innovation across a broad medical front.

Brain Surgery and Radiation Therapy. Robotics and 3-D image fusion have been especially useful in brain surgery. New techniques are being demonstrated by image-guided stereotaxic resectioning of brain tumors by Raymond Sawaya and others at the M. D. Anderson Cancer Center of the University of Texas at Houston. Among the achievements is a frameless stereotactic system—the Unimation PUMA 200 robot, developed by Y. S. Kwoh. The computerized arm of that robot adjusts probe trajectories in various directions.[27]

A related development is the computerized "viewing wand," a CT-stereotactic device developed by Patrick J. Kelly for frameless devices, which continuously provides the location of the operating site in the brain and directs the surgeon toward that target.[28] It also works as a 3-D space-monitoring device. The wand has a freely mobile, articulated mechanical arm attached to a computer that holds the patient's preoperative imaging data. The computer interactively displays CT or MRI images of the patient as a reconstructed 3-D model or as an orthogonal formatted image. The surgeon uses the mechanical arm to touch a series of reference marks on the patient while the computer displays a model of the probe in relation to the 3-D model or the reformatted anatomical display. The surgeon marks the corresponding points on the 3-D model then "locks" the patient and model image together. The wand's maximum detection error is reported as 2.5 mm. It is rated particularly useful for skull base surgery, which is an extremely complicated anatomic region. The wand is ideal for navigating to and resectioning the tumors.

Another stereotactic system from Kelly and associates, called Compass, combines a microscope, laser tools, and computer simulation for image-directed excisions of tumors. It provides a heads-up display of CT- or MRI-defined tumors obtained through a microscope. Compass encircles the patient's head during CT, MRI, and angiographic imaging and creates computer-generated 3-D maps of the tumor. During subsequent surgery with a robotic device, the device's head-holding reference system holds the head in the same position that was used for image collection. The surgical field thus corresponds to the computer-generated slice images of the field.

Similar use of image fusion is employed during neurosurgery on deeply embedded brain tumors by surgeons at Brigham Women's Hospital, Boston. Ferrenc A. Jolesz overlays MRI images with video images to locate tumor margins within 0.5 mm accuracy.[29] Meanwhile, Henry B. Fuchs of the University of North Carolina has built a VR model that lets a radiotherapist visualize a tumor, reconstructed from 3-D CT scans, inside the patient.[30] He can then plan radiation trajectories that give lethal doses to the tumor while not damaging normal organs.

Maxillo-Facial Surgery and Virtual

The virtual reality simulation of tendon transplantation surgery developed by MusculoGraphics, Inc.

Endoscopy. The use of 3-D images and models have brought major advances in plastic surgery. At Brigham Women's Hospital, David E. Altobelli created 3-D images from the CT scan of a child with craniofacial dysostosis, a bony deformity in which only half of the face grows. In what is normally an extremely difficult procedure, the surgeon used the 3-D model to rearrange the bones to symmetrically match the healthy side of the face.[31]

At the Dartmouth University Medical Center, Joseph M. Rosen uses a VR model of a face with deformable skin for practicing plastic surgery procedures and predicting outcomes before he makes his first incision on a patient.[32]

Similarly, MusculoGraphics, Inc., of Evanston, Illinois, offers a family of SIMM (Software for Interactive Musculoskeletal Modeling) virtual models that calculate joint movements that limb muscles can generate at any body position.[33] The firm's Computer-Assisted Surgery systems simplify and automate many surgical procedures. A surgeon performing a tendon transplant on a lower leg, for example, can use SIMM/Gait to "walk" the leg in order to predict short- and long-term surgical outcomes. For the DoD, MusculoGraphics is developing a Limb Trauma Simulator that models gunshot wounds to the leg.

At the GE Medical Corporate Research Center, William E. Lorensen and others have developed a "virtual endoscope" that lets a physician view internal surfaces from any perspective, including from behind tissue folds or around difficult flexures. The technique lets a doctor look through a

tumor to determine penetration of the wall or detect metastases. By incorporating multispectral analysis of the image, the technique offers an "optical biopsy" that could replace current flexible endoscopic examinations. The method would also be beneficial to other medical disciplines, especially urology, pulmonology, and ear-nose-throat.[34] High-accuracy virtual endoscopy holds promise for both medical education and telesurgery.

Rehabilitation and Assistive Devices. Virtual environments have become so useful in rehabilitative medicine that an annual conference is held on the subject. Virtual environments have been created for exploration from a wheelchair.[35] A specialist using a BioControl, Inc., eye-tracking device has allowed a quadriplegic girl to interact with the outside world before her disability causes her to become too introverted to communicate.[36]

The use of immersive VR for cognitive rehabilitation of brain-damaged patients is under study by an Italian team under a project called ARCANA (Advanced Research for the Computer-based Assessment of Neurophysiological Ailments). ARCANA uses VR models to help clinical psychologists, neurophysiologists, and cognitive therapists work with cognitively impaired people.[37] German research laboratories are perfecting datagloves, biosignals, and other VR techniques that will facilitate communication for the physically challenged.[38]

Data Visualization. VR can visualize extremely large data fields, such as medical databases. Intelligence and government agencies are technical leaders in data visualization, image processing, and other techniques that let analysts rapidly scan such data fields. One example is a 3-D representation of war injuries recorded in the Viet Nam Database. By using three axes of information, researchers can visualize as clusters complex combinations of wounds, organs injured, mortality, and other data.[39] Surgeons can draw on research and development activities in IT by the U.S. intelligence community, the government, and contracting commercial and academic developers.

"Operating Environment of the Future" as envisioned by Northrop Grumman

Surgical Facility Design. Another medical use of VR—designing the operating room of the future—is being pursued by the MIT School of Architecture and the Harvard Graduate School of Design.[40] A team from both schools is assessing new spatial arrangements, the use of smart materials and intelligent equipment, and the integration of information sources, imaging systems, and new treatment modalities. VR will be used for end-to-end planning of the operating room, allowing hospital administrators, surgeons, anesthesiologists, technicians, and others to test the facility in virtual form before it is built.

Future Developments and Issues for Medicine in the Year 2000

Information technologies and laparoscopic surgical techniques have begun the revolution in medical technology, but it is far from complete. On the technology side, improving the accuracy of VR organ models is considered critical. That includes measuring tissue properties to get a simulation baseline.

Adding intelligence to the pixels (the tiny "picture elements" of a display) would allow the addition of dynamic changes in certain organs. The technique called *deep pixels* could let every pixel store massive amounts of information, such as anatomic function, color, texture, dynamic movement, physiologic parameters, and biochemical values. The organ represented by those pixels could have all the properties of living tissue and permit a person to interact with it as if it were real. Another needed improvement is incorporating smell and sound in surgical VR. The large area of the cerebral cortex used for smell suggests that smell can be used to advantage in simulation.

More cooperation is needed for virtual teaming, which allows widely separated medical specialists to collaborate on a single patient as though they were in the same operating room.

VR-aided laparoscopic surgery poses unusual challenges to regulators, administrators, and health professionals. Historically, the medical community has accepted a lag time of twenty to thirty years between lab development of a technique and its broad use by doctors or surgeons. But because of the increasing integration of surgical VR with advances in fast-moving commercial IT markets, surgical innovations are occurring faster than traditional clinical evaluation and implementation—much less regulatory review—have traditionally moved. The lag threatens to slow the fielding of new innovations.

Meanwhile, market forces in the United States alone promise potentially extraordinary growth for telesurgery and VR-aided minimally invasive surgery.[41] The most eager consumers for such procedures are members of the large, aging baby-boom population that will demand high-quality, leading-edge medical care even in a capitation-driven marketplace.

Telesurgery will allow domestic surgeons and clinics to create lucrative overseas practices, as well as practices in remote areas of the United States.

In short, VR-aided surgery will continue to benefit from advances in simulation, VR, displays, sensors, actuators, and high-bandwidth data links. Market forces encouraging wider use of minimally invasive surgery and its extension to more demanding medical problems will create a critical mass of technologists, medical entrepreneurs, and health insurers who can integrate commercial ITs into highly profitable systems.

Medicine has taken its first steps into the next millennium.

♦

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Use of a Mock Trial Simulation to Enhance Legal Medicine Education for Medical Students

Theodore R. LeBlang

The importance of legal medicine education for medical students has been a noteworthy theme in the literature for more than forty years. As early as 1952, the Committee on Medicolegal Problems of the American Medical Association stated its belief that "in the practice of medicine, no physician can avoid contact with the law and that no medical student should be permitted to receive his degree without instruction in his legal duties to his patients, community, and government."[1] That thinking has been consistently reaffirmed by commentators since the early 1950s. Moreover, the wisdom of teaching medical students about legal medicine is seldom challenged seriously today.[2]

In emphasizing the importance of including the study of the humanities in medical education, Jordan Cohen, president of the Association of American Medical Colleges, recently explained that "legal reasoning and the study of the legal system should make the physician a better advocate for the patient and a more knowledgeable participant in public debate on issues of health care services."[3] In that regard, commentators have emphasized that the first goal of teaching legal medicine should be to enhance physician effectiveness in clinical medicine; the second goal should be to improve the ability of physicians to participate meaningfully in the administration of justice.[4] In the latter context, it has been recognized that legal medicine education can meaningfully influence physician attitudes toward law, the legal system, and the courts, thus fostering the type of productive working relationship between physicians and attorneys that benefits both patients and physicians.[5]

Against the background of those considerations, the study of legal medicine has become more common in medical schools throughout the United States. Of 109 medical schools responding to a survey conducted in 1992, ninety indicated that they were teaching legal medicine as a required or elective part of their curriculum.[6]

At Southern Illinois University (SIU) School of Medicine, legal medicine teaching began in the mid-1970s as part of the Program of Law and Medicine (Program), which is based in the Department of Medical Humanities. Program coursework is comprehensive and well developed and makes use of various teaching modalities, including lectures, seminars, case-based tutor group discussions, and simulated patient encounters.

Perhaps the highlight of the required curriculum in legal medicine is the mock trial reenactment of the landmark Illinois case *Darling v. Charleston Community Memorial Hospital*. The mock trial concludes the formal program of required undergraduate instruction in legal medicine and is viewed as an essential adjunct to a full and complete legal medicine learning experience. Since 1977, all School of Medicine students have been required to participate in that important courtroom simulation.

Before discussing the mock trial in greater detail, it is important to place the learning experience in context. Thus, a description of the Program of Law and Medicine follows, with emphasis on its core content.

Legal Medicine Coursework

The Program of Law and Medicine, which began in the mid-1970s, is an academic program based in the Department of Medical Humanities. Although teaching activity forming part of the various programs in the department is integrated throughout the four-year curriculum, required instruction in legal medicine is concentrated during the clinical clerkship year. It is at that time that students rotate through clerkships representing the major medical specialties. Students also participate in the multidisciplinary Medical Humanities clerkship.

The Department of Medical Humanities offers a curriculum designed to provide students with core knowledge in the humanities, emphasizing application of the content and methodologies of humanities disciplines to the practice of medicine. Substantive areas of teaching emphasis include ethics, health policy, law, medical history, philosophy, and psychosocial care. The four-week Medical Humanities clerkship is divided into two segments—Medical Humanities A and Medical Humanities B. Each segment lasts two weeks.

Medical Humanities A is delivered during the junior year and focuses on the physician-patient relationship. Issues of confidentiality and privacy, informed consent, standards of care (malpractice), withholding/withdrawing life-sustaining treatment, assisted death, palliative care, organ donation, physician-patient communication, and psychosocial care are addressed in the context of lectures, panel discussions, case conferences, tutor group activities, and simulated patient interactions. Throughout the clerkship, teaching emphasis is placed on strengthening the physician-patient relationship.

Medical Humanities B is delivered early in the senior year and is comprised of two content areas: the physician's role in the administration of justice and the physician's role in society, with emphasis on current changes in health care delivery. During the first part of the clerkship, students are exposed to an overview of the judicial process as well as the manner in which physicians serve as expert witnesses in civil and criminal trial proceedings. Systems of medical-legal investigation also are discussed, with emphasis on forensic medicine. Students further explore the controversy surrounding physician participation in capital punishment. Finally, a mock trial is staged to permit students to observe the trial process in a courtroom setting. During the second part of the clerkship, students examine a variety of important issues relating to health care delivery in the United States. Those issues include the following: economic considerations bearing upon health care delivery, health care financing, access to and avail-

ability of health care, the changing accountability of physicians in an evolving health care system, and clinical, ethical, legal, and policy aspects of managed care.

Educational activities in the Program of Law and Medicine are mastery based, with learning objectives that are designed to convey to each student relevant faculty expectations. Learning objectives are contained in modules, which are the basic learning components of the curriculum. Modules are self-contained curriculum units, wherein faculty designate specific learning objectives, required and recommended learning activities, and criteria for successful completion.

Presentation of legal medicine modules during the clerkship segment of the curriculum allows students to become familiar with important legal principles at a time when those principles are particularly relevant to their clinical activities. Within the framework of the four-week Medical Humanities clerkship, fourteen of thirty-five learning modules focus entirely or in pertinent part on issues arising at the interface of law and medicine. In addition to the modules that form the Medical Humanities clerkship, numerous additional modules focus on issues that are uniquely relevant to the medical specialties of obstetrics and gynecology, pediatrics, psychiatry, and internal medicine. Those modules are integrated directly into the respective clinical clerkships.

In the Obstetrics and Gynecology clerkship, one module focuses on legal aspects of abortion. In the Pediatrics clerkship, integrated modules focus on legal aspects of child abuse and neglect, parent-child conflicts in adolescent medicine, and limits on parental authority to make decisions involving medical care for young children. In the Psychiatry clerkship, a module focuses on issues involving the following topics: civil commitment and patients' rights following involuntary hospitalization; concepts of insanity, competency, and testamentary capacity; confidentiality and privacy within the psychiatrist-patient relationship; and negligence issues, with emphasis on potential areas of liability, including the failure to warn third parties of a patient's dangerous propensities. In the Internal Medicine clerkship, a multidisciplinary module on domestic violence focuses on clinical, legal, and social considerations relating primarily to partner abuse. Thus, throughout the clinical clerkship segment of the undergraduate curriculum, students participate in numerous required learning modules addressing important issues in legal medicine. The final learning experience in this sequence of legal medicine modules is the mock trial. Use of the mock trial as a conclusion to Program of Law and Medicine instruction enhances the overall legal medicine learning experience.

Mock Trial

Viewed as an essential component of legal medicine instruction at SIU School of Medicine, a mock trial is staged to permit students to observe and participate in the trial process in a courtroom setting. It involves a three-and-a-half-hour reenactment of *Darling v. Charleston Community Memorial Hospital.* Perhaps one of the most-often-cited cases in the United States involving malpractice liability of a hospital, the case is rich with facts that trigger passionate responses on the part of medical students. The case involves a lawsuit brought on behalf of Dorrence Kenneth Darling II to recover damages arising out of a below-the-knee amputation performed on his right leg.

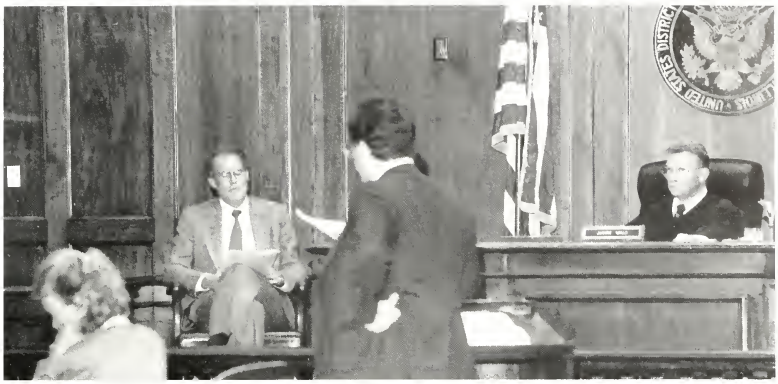
Under the facts of the case, on November 5, 1965, Darling, a student at Eastern Illinois University, sustained a broken right leg while playing defensive left halfback as a member of the Eastern Illinois University football team. Darling was taken to the emergency room of Charleston Community Memorial Hospital, at which time Dr. John Alexander, the on-call physician, was contacted to come to the hospital to treat him. A comminuted fracture of the right tibia and fibula was diagnosed and, with the assistance of hospital staff, Darling's leg was set in a cast. Thereafter, during the period of his hospitalization, from November 5 through November 19, Darling's condition deteriorated, eventually necessitating transfer to Barnes Hospital in St. Louis.

During the first three days of hospitalization, the plaintiff complained of pain constantly and nurses' notes indicated that the foot of the injured limb became swollen and dark in color. On November 6, Alexander cut a "notch" in the cast around the toes and, on November 7, when the plaintiff complained of loss of feeling in his toes, Alexander cut the cast approximately three inches up from the foot. On November 8, when it was evident that the foot and toes were still swollen and painful, Alexander split the cast in its entirety. Subsequently, during the period from November 9 through November 19, complaints of severe pain continued, the leg began to develop a foul odor, and it became gangrenous.

On November 19, Darling was transferred by ambulance to Barnes Hospital, where he came under the care of Dr. Fred Reynolds, head of Orthopedic Surgery at Washington University School of Medicine. Darling continued as a patient for approximately one month and was discharged home on December 16. He was readmitted to Barnes Hospital on December 27 for a two-day stay and then subsequently readmitted on January 16. Approximately three weeks later, after all efforts to treat the gangrenous condition of Darling's leg were unsuccessful, it was amputated at a point below the knee.

A malpractice lawsuit containing numerous allegations of negligence was subsequently initiated against Alexander and Charleston Community Memorial Hospital. Prior to trial, Alexander settled the case for $40,000. Darling and his father proceeded to trial against the hospital as the only remaining defendant in the case. Following a two-week jury trial, a verdict was rendered in favor of the Darlings in the amount of $150,000. An appeal was taken during which the court focused attention on the hospital's assertion that it should not be found liable on the basis that it had no independent duty to oversee the care and treatment provided to the patient. Disagreeing with that assertion, the court emphasized that present-day hospitals do considerably more than furnish facilities for medical care and treatment. They employ large numbers of persons, charge patients for medical care rendered, and undertake collection for such services. Moreover, patients who avail themselves of hospital facilities expect that the hospital will attempt to cure them. Thus, as a matter of law, the court concluded that hospitals have independent articulable duties and responsibilities with respect to care and treatment of patients.

Further appeal to the Illinois Supreme Court resulted in affirmation of the jury verdict against the hospital. The state supreme court concluded that the verdict was fairly premised upon any of the



In the United States District Court for the Central District of Illinois, counsel for the defendant, Charleston Community Memorial Hospital, undertakes direct examination of a School of Medicine faculty member portraying the role of hospital administrator Wayne Annis. Judge Richard H. Mills presides.

following violations of the applicable standard of care:

> [Failing] to have a sufficient number of trained nurses for bedside care of all patients at all times capable of recognizing the progressive gangrenous condition of the plaintiff's right leg, and of bringing the same to the attention of the hospital administration and to the medical staff so that adequate consultation could have been secured and such conditions rectified; . . . [and failing] to require consultation with or examination by members of the hospital surgical staff skilled in such treatment; or to review the treatment rendered to the plaintiff and to require consultants to be called in as needed.[7]

Given the fact that the *Darling* case involved a two-week jury trial, extensive witness testimony is available upon which to base development of an interesting mock trial reenactment. To provide a realistic forum within which to conduct the trial, the courtroom of the United States District Court for the Central District of Illinois is used. With its rich, traditional, dark wood paneling, this stately courtroom is visually impressive to medical students and consistent with their preconceived notions of a "classic" courtroom environment.

Presiding over the mock trial is a volunteer community trial judge who serves as a member of the adjunct faculty of the Department of Medical Humanities. Through the years, four judges have served: United States District Judge J. Waldo Ackerman; Illinois Supreme Court Justice Benjamin K. Miller; United States District Court Judge Richard H. Mills; and Chief Circuit Court Judge Sue E. Myerscough of the Seventh Illinois Judicial Circuit. To ensure that the mock trial does

not conflict with other ongoing judicial activities, it is scheduled to occur from 7:15 P.M. to approximately 10:45 P.M., as an evening activity during the clerkship.

Other participants in the mock trial include four community trial attorneys, who are recognized for their expertise in prosecuting and defending medical malpractice cases. Two of the attorneys are assigned to represent the plaintiff, and two are assigned to represent the defendant; all are members of the adjunct faculty of the department. Involvement of multiple attorneys during the mock trial provides medical students with exposure to a diversity of courtroom styles, tactics, and demeanor. Other School of Medicine faculty, residents, and administrators volunteer to play the remaining mock trial roles as follows: the plaintiffs, Darling and his father; Alexander, the treating physician; a hospital nurse, Anna Myers, who was integrally involved in Darling's care; Reynolds, a physician from Barnes Hospital, the plaintiff's expert witness; Wayne Annis, hospital administrator for the defendant, Charleston Community Memorial Hospital; and Mack Hollowell, a physician on staff at the hospital and the defendant's expert witness. All mock trial participants are provided with a compendium of case materials to prepare for the proceeding. A brief rehearsal occurs immediately prior to the mock trial in the judge's chambers at the federal district court.

The mock trial is conducted in a serious and formal manner and is designed to exemplify important aspects of the trial proceeding. Court is first called into session by the clerk of the court with the typical formalities that attend such a proceeding. Subsequently, throughout the mock trial, the clerk administers the traditional oath to jurors and to all witnesses.

The trial begins with voir dire (examination) of jurors, to exemplify the jury selection process. Jurors consist of medical students who self-select to occupy the fourteen seats in the jury box. The remaining students, who constitute the balance of the entire senior class, occupy courtroom seats that are typically filled by public observers. The jury selection process, although abbreviated, includes an interchange that results in the dismissal of a juror who the court (or counsel) determines is unable to be fair and impartial in deliberating about the facts of the case.

Following voir dire, one attorney for the plaintiff and one attorney for the defense make opening statements. Thereafter, the plaintiff's witnesses are examined and cross-examined in a manner consistent with applicable rules of civil procedure. Various props are utilized as evidence exhibits, including the following: rules and regulations of the Illinois Department of Public Health under the Hospital Licensing Act, relevant standards for hospital accreditation promulgated by the Joint Commission on Accreditation of Hospitals (now JCAHO), and hospital medical records. Various textbooks also are used for purposes of cross-examination.

Attorneys are asked to interpose appropriate objections throughout the course of examination and cross-examination of witnesses in an effort to portray to students the types of objections that may be made during the course of a trial. Rulings are then made by the judge, often with appropriate explanation to enhance the learning experience. Occasional sidebar meetings of attorneys at the judge's bench also are staged to enhance the reality of the simulation.

After presentation of the plaintiff's witnesses, there is a brief recess, which is followed by defense presentation of witnesses. Again, direct- and cross-examination are conducted by attorneys consistent with standard courtroom procedure. Following presentation of defense witnesses, the parties rest. Due to applicable time constraints, no rebuttal testimony is offered.

Closing arguments follow, during which one attorney for the plaintiff and one attorney for the defense address the jury in a manner consistent with typical closing arguments, albeit abridged. Pertinent jury instructions are then read to members of the jury by the trial judge, who directs the jurors to commence deliberations. Concluding remarks are then offered by the judge, and students are given an opportunity to vote in favor of or against the plaintiff or defendant by show of hands. A question-and-answer session follows, during which students may pose questions to the judge, the trial attorneys, and Medical Humanities faculty who are present.

Pedagogical Considerations

It has been recognized that legal medicine education in medical schools must be innovative and creative and should be presented through a multitude of formats.[8] Various types of simulations have been highlighted as affording excellent opportunities to maximize the effectiveness of legal medicine teaching.[9] Mock trials have been described as extremely useful teaching tools that can assist medical students in understanding legal medicine as well as the important role of the physician in the administration of justice.[10] In 1994, Stuart Levine and Henry Pinsker observed that although use of a mock trial as a teaching tool in medical education has rarely been reported, "it is a powerful tool for teaching about the interface between medicine and the law."[11] Moreover, they observed that "malpractice cases . . . not only demonstrate the issues clearly, but they also hold the attention of the audience most effectively."[12]

Those observations of various commentators echo the long-held view of the Department of Medical Humanities that use of a mock trial as a conclusion to required legal medicine coursework for medical students maximizes the overall learning experience. It permits students to integrate and apply their medical-legal expertise in observing and analyzing a trial proceeding.

It should be emphasized that the mock trial is designed to be more than a passive, observational, learning experience.[13] To maximize the value of the simulation, students are required to undertake specific preparation for the courtroom proceeding and to participate in the simulation in an interactive manner. All students are required to write an analysis of the mock trial, demonstrating their ability to: (1) describe the fact situation of the underlying litigation in the case, (2) define and describe the significant legal issues, (3) identify and describe the roles of the participants, and (4) identify and describe the components of the trial process, including voir dire, opening statements, direct- and cross-examination of witnesses, closing arguments, and jury instruction. Of greatest importance with respect to the written essay is the interactive nature of the assignment.

Students are required, in advance of the mock trial, to carefully read the approximate seventy-five-page *Darling* case and to participate in a pretrial discussion of

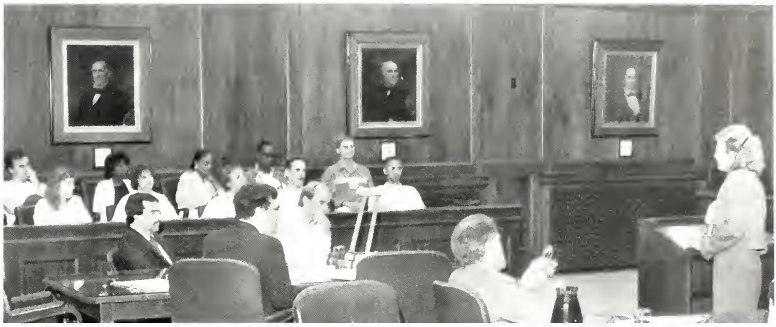
faculty expectations regarding applicable learning objectives. Further, as an additional part of the learning experience, students are required to prepare an approximately four-page typed analysis of the mock trial based upon personal observation during the three-and-a-half hour simulation. Students are specifically asked to assume the perspective of either a juror, one of the trial attorneys, a particular witness, the plaintiff, the defendant, or the trial judge, and then to describe and analyze the trial proceeding as viewed through the eyes of the selected participant. Students demonstrate, through that "first-person" description, an overview of the mock trial, highlighting occurrences of importance to the individual whose perspective they have assumed. Students therefore must apply their knowledge of the roles of the various participants in the mock trial while identifying and describing the components of the trial process that would be viewed as significant by the participant whose perspective they have assumed.

In order to fulfill that requirement of the learning activity, students must be attentive to all occurrences during the mock trial and record personal notes of activities that they deem important in light of their first-person evaluation of the experience. Thus, the student who assumes the perspective of a juror, as an example, will likely focus broadly on the testimony of witnesses as well as the relative effectiveness of attorneys for the defense and the plaintiff. If a student assumes the perspective of an attorney, then the essay likely will focus more selectively upon the attorney's tactics and strategies during the trial, with emphasis on approaches used during direct- and cross-examination of witnesses. Students assuming the perspective of the plaintiff or the defendant will focus on the effectiveness of witness testimony and the attorneys' opening statements and closing arguments. Students who assume the perspective of the trial judge will focus more on the responsibilities of the judge to ensure fairness, to properly educate the jury about its responsibilities, and to rule properly on objections and motions. Because medical students have completed all required coursework in legal medicine at the time they undertake the essay, they are able to rely upon a considerable database of statutory law, common law, and rules of courtroom procedure in completing their analyses.

During the past twenty years, students have been particularly creative in their approach to the essays, evidencing a surprisingly high degree of sophistication in the context of assuming the various perspectives of all participants in the mock trial simulation. Moreover, students have indicated that they gained more from the learning experience than if they had functioned simply as passive observers.

Commentators have observed that there is strong evidence that students give high marks to mock trials as an experiential approach to learning about legal issues.[14] That is consistent with the views expressed by medical students who have participated in the Department of Medical Humanities mock trial. Written feedback from students has been quite favorable over the years. Of particular interest is a more focused set of student feedback obtained in September of 1993.

In that year, students were asked to complete a reasonably detailed feedback form in addition to the general feedback form utilized to evaluate the overall clerkship. Among the questions posed to



Counsel for the plaintiff presents closing arguments to medical student jurors. At defense counsel table, in foreground, is hospital administrator Annis. Co-counsel for the plaintiff, along with the resident and medical school faculty member portraying the roles of Dorrence Kenneth Darling II and his father, are seated at plaintiff's counsel table near jury.

students were the following:

1. Did attending the mock trial improve your understanding of material on law and the legal system to which you were previously exposed in the curriculum? If so, describe how.
2. Did attending the mock trial improve your understanding of the trial process and the physician's role in the administration of justice? If so, describe how.
3. What was your overall reaction to the mock trial learning experience? In general, how did it compare with your other learning experiences at the School of Medicine?

Because student feedback was provided in narrative form, subjective categorization of responses was required in order to offer a meaningful summary. However, given that caveat, the author views the following summary as fairly portraying student responses.

In response to the first question, fifty-six out of sixty-three respondents indicated that the mock trial clearly improved their understanding of law and the legal system. Three indicated that it improved their understanding somewhat, and four indicated that it improved their understanding minimally or not at all. In response to the second question, fifty-three out of sixty-one respondents indicated that the mock trial clearly improved their understanding of the trial process and the physician's role in the administration of justice. Four indicated that it somewhat improved their understanding, and four indicated that it improved their understanding minimally or not at all. In response to the third question, forty-eight out of fifty-nine respondents rated the mock trial as a better-than-average learning experience (of the forty-eight, thirty-four rated it as excellent or very good, and six observed that it was one of the best learning experiences while in medical school). Again, it should be emphasized that the summaries of student feedback are based upon subjective categorization of

general written comments offered in response to the questions noted above. Nevertheless, the feedback offers useful insights regarding the overall success of the mock trial simulation as a legal medicine learning experience.

Conclusion

The mock trial represents an extremely important and valuable use of simulation in the context of educating medical students about legal medicine. It affords medical students an opportunity to evaluate the application of important legal principles within the framework of a medical malpractice case being adjudicated in a court of law. Moreover, it enhances student understanding of the important role of the physician in the administration of justice as well as the manner in which the legal system operates. That is particularly important in view of the fact that many physicians will be called upon throughout their careers to testify as witnesses in a variety of civil and criminal proceedings.

Testimony often will be required in situations where patients have been injured, whether as a result of work-related accidents, automobile collisions, product-related injury, domestic violence, sexual assault, or child abuse. Testimony also may be required in a variety of other legal proceedings where patient interests are involved, such as will contests, child custody disputes, and civil commitment proceedings. Because of the numerous areas where law and medicine converge, physicians may anticipate being drawn into a variety of patient-related disputes wherein a legal resolution may be required.[15] Furthermore, legal medicine education can meaningfully influence physician attitudes toward law, the legal system, and the courts, thereby engendering a more positive working relationship between physicians and attorneys that will enhance the physician-patient relationship and permit the physician to function as an important advocate on behalf of a patient's best interests.[16]

Against the background of those considerations, incorporation of a mock trial simulation in a curriculum designed to expose medical students to legal medicine education has tremendous pedagogical value. It is a distinctive educational technique that deserves to be more widely employed,[17] and medical schools are urged to consider not only the approach outlined in this article but to consider other innovative strategies for simulating physician participation in the administration of justice.

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Notes

1. L. J. Regan, "Report of Committee on Medicolegal Problems: A Suggested Course in Legal Medicine for Medical Schools," *JAMA* 150 (1952): 716.

2. Marshall B. Kapp, "Teaching Legal Medicine in Medical Schools," *Journal of Legal Medicine* 8 (1987): 94–103; Barbara B. Blechner, Christie L. Hager, and Nancy R. Williams, "The Jay Healy Technique: Teaching Law and Ethics to Medical and Dental Students," *American Journal of Law and Medicine* 20 (1994): 439–55.

3. Jordan Cohen, "The Humanities and Medical Education," *Academic Medicine* 70 (1995): 755–56.

4. Peter L. Williams and William Winslade, "Educating Medical Students about Law and the Legal System," *Academic Medicine* 70 (1995): 777–86.

5. Theodore R. LeBlang et al., "The Impact of Legal Medicine Education on Medical Students' Attitudes Toward Law," *Journal of Medical*

Education 60 (1985): 279–87; Kapp, "Teaching Legal Medicine," 96.

6. Williams and Winslade, "Educating Medical Students," 777, 780. In a more recent survey of internal medicine chief residents, 92 percent of those responding (n = 159) indicated that medical legal issues played an important role in medical practice and 76 percent felt that legal medicine education should form part of the undergraduate medical education curriculum. Chad D. Kollas, "Exploring Internal Medicine Chief Residents' Medicolegal Knowledge," *Journal of Legal Medicine* 18 (1997): 47–61.

7. *Darling v. Charleston Community Memorial Hospital,* 33 Ill. 2d 326, 211 N.E.2d 253, 258 (1965).

8. Kapp, "Teaching Legal Medicine," 98.

9. Williams and Winslade, "Educating Medical Students," 783.

10. Terry Lewis and Suzanne Prior, "With Mock Trials, Students Learn by Doing," *Florida Bar Journal* 67 (Oct. 1993): 30–34; Richard Smith, "Using a Mock Trial to Make a Difficult Clinical Decision," *British Medical Journal* 305 (1992): 1284–87; Michael Langford, "The Moot Court in Teaching Bioethics," *Nurse Education Today* 10 (1990): 24–30; Fay Rozovsky, "Symposium on Teaching Legal Medicine: Introduction," *Journal of Legal Medicine* 8 (1987): 91–93.

11. Stuart Levine and Henry Pinsker, "The Mock Trial in Psychiatric Staff Education," *Bulletin of the American Academy of Psychiatry and the Law* 22 (1994): 127–32, quotation from 131.

12. Ibid., 131.

13. See Meg Wilkes Karraker, "Mock Trials and Critical Thinking," *College Teaching* 41 (1993): 134–37. Karraker observes that the trial merely will serve as recreation unless the simulation is prefaced with a clear discussion of the learning objectives and is followed by a conscientious debriefing. She further states that such a "debriefing can take the form of deliberation by the jury and oral or written accounts prepared by reporters attending the trial, or a class discussion led by the instructor" (136).

14. John J. Whyte, "Mock Ethics Trial for Medical Students and Law Students," *Academic Medicine* 68 (1993): 844; Sherry Warden et al., "The Effect of a Mock Trial on Nursing Students' Ability to Make Clinically Sound Legal Judgments," *Nurse Educator* 19 (May/June 1994): 18–22.

15. Kapp, "Teaching Legal Medicine," 95.

16. LeBlang et al., "Impact of Legal Medicine Education," 284–86.

17. Levine and Pinsker, "Mock Trial in Psychiatric Staff Education," 127.

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